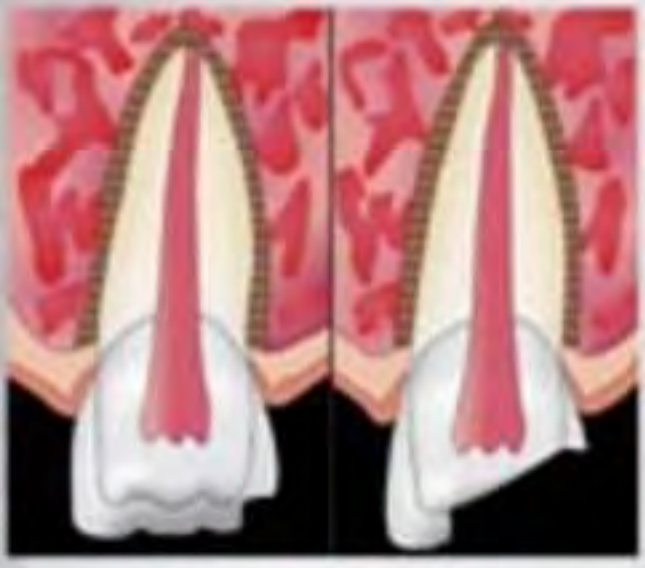
ADVANCED ENDODONTICS



R Nageswar Rao

JAYPEE

Foreword
PNR Nair

Advanced Endodontics

"There is always the hope of tomorrow to brighten the clouds of today,
There's always a corner for turning, no matter how weary the way.
So just look ahead to tomorrow and trust that you'll find waiting there,
The sunlight that seemed to be hidden by yesterday's clouds of despair."

Advanced Endodontics

R Nageswar Rao MDS

Chairman
Former Professor and Head
Department of Conservative Dentistry and Endodontics
SDM College of Dental Sciences and Hospital
Dharwad, Karnataka, India

JAYPEE BROTHERS MEDICAL PUBLISHERS (P) LTD

St Louis (USA) • Panama City (Panama) • New Delhi • Ahmedabad • Bengaluru
Chennai • Hyderabad • Kochi • Kolkata • Lucknow • Mumbai • Nagpur

Published by

Jitendar P Vij
Jaypee Brothers Medical Publishers (P) Ltd

Corporate Office
4838/24, Ansari Road, Daryaganj, **New Delhi** 110 002, India, Phone: +91-11-43574357, Fax: +91-11-43574314

Registered Office
B-3, EMCA House, 23/23B Ansari Road, Daryaganj, **New Delhi** 110 002, India
Phones: +91-11-23272143, +91-11-23272703, +91-11-23282021, +91-11-23245672, Rel: +91-11-32558559
Fax: +91-11-23276490, +91-11-23245683, e-mail: jaypee@jaypeebrothers.com, Website: www.jaypeebrothers.com

Branches

- 2/B, Akruti Society, Jodhpur Gam Road Satellite
  Ahmedabad 380 015, Phones: +91-79-26926233, Rel: +91-79-32988717
  Fax: +91-79-26927094, e-mail: ahmedabad@jaypeebrother.com
- 202 Batavia Chambers, 8 Kumara Krupa Road, Kumara Park East
  Bengaluru 560 001, Phones: +91-80-22285971, +91-80-22382956, Rel: +91-80-32714073
  Fax: +91-80-22281761, e-mail: bangalore@jaypeebrothers.com
- 282 IIIrd Floor, Khaleel Shirazi Estate, Fountain Plaza, Pantheon Road
  Chennai 600 008, Phones: +91-44-28193265, +91-44-28194897, Rel: +91-44-32972089
  Fax: +91-44-28193231, e-mail: chennai@jaypeebrothers.com
- 4-2-1067/1-3, 1st Floor, Balaji Building, Ramkote Cross Road
  Hyderabad 500 095, Phones: +91-40-66610020, +91-40-24758498, Rel:+91-40-32940929
  Fax:+91-40-24758499, e-mail: hyderabad@jaypeebrother.com
- No. 41/3098, B & B1, Kuruvi Building, St. Vincent Road
  Kochi 682 018, Kerala, Phones: +91-484-4036109, +91-484-2395739, +91-484-2395740, e-mail: kochi@jaypeebrothers.com
- 1-A Indian Mirror Street, Wellington Square
  Kolkata 700 013, Phones: +91-33-22651926, +91-33-22276404, +91-33-22276415
  Fax: +91-33-22656075, e-mail: kolkata@jaypeebrothers.com
- Lekhraj Market III, B-2, Sector-4, Faizabad Road, Indira Nagar
  Lucknow 226 016, Phones: +91-522-3040553, +91-522-3040554, e-mail: lucknow@jaypeebrothers.com
- 106 Amit Industrial Estate, 61 Dr SS Rao Road, Near MGM Hospital, Parel
  Mumbai 400 012, Phones: +91-22-24124863, +91-22-24104532, Rel: +91-22-32926896
  Fax: +91-22-24160828, e-mail: mumbai@jaypeebrothers.com
- "KAMALPUSHPA" 38, Reshimbag, Opp. Mohota Science College, Umred Road
  Nagpur 440 009 (MS), Phones: Rel: +91-712-3245220, Fax: +91-712-2704275, e-mail: nagpur@jaypeebrothers.com

North America Office
1745, Pheasant Run Drive, Maryland Heights (Missouri), MO 63043, USA Ph: 001-636-6279734
e-mail: jaypee@jaypeebrothers.com, anjulav@jaypeebrothers.com

Central America Office
Jaypee-Highlights Medical Publishers Inc., City of Knowledge, Bld. 237, Clayton, Panama City, Panama Ph: 507-317-0160

Advanced Endodontics

First Edition: **2009**

ISBN 978-81-8448-746-6

Typeset at JPBMP typesetting unit
Printed at

Dedicated
to
All my
Postgraduate Students

Foreword

Universität Zürich
Centre of Dental and Oral Medicine

Institut für Orale Biologie
Abteilung für Orofaziale Strukturen
und entwicklung

Plattenstrasse 11
CH-8032 Zürich
Switzerland

Tel. +41 44 634 31 42
Fax +41 441 312 32 81
ram.nair@zzmk.uzh.ch
www.dent/uzh.ch/ob

Dr. Dr. h.c. P.N.R. Nair
Senior Scientist

All great rivers have humble origins. From its modest beginning in 1986, the SDM College of Dental Sciences and Hospital, Dharwad, Karnataka has grown into the foremost institution of dental medicine in India in a relatively short span of two decades. The college has been imparting undergraduate and postgraduate dental education of a high standard, conducting research and providing oro-facial health care to the rural population around Dharwad and beyond. It has been training dental health care personnel of different skills and various levels.

I had the rare honour to associate myself with the College from its very inception. Therefore, it is a matter of great professional pride and satisfaction for me to note that the SDM College is the only one among the 161 dental colleges in the country to have received the 'Five Star' accreditation from the National Assessment and Accreditation Council (NAAC) of India. It was also the first and now one of the two centres in India for primary examinations leading to the FDSRCS and the FRCS of the Royal College of Surgeons, Glasgow, United Kingdom. It is, therefore, not incidental that the SDM College of Dental Sciences and Hospital has several scores of publications in international journals and has accumulated expertise and materials that can be shared with students, researchers and teachers.

The *Advanced Endodontics* by Dr R Nageswar Rao, Head of the Department of Conservative Dentistry and Endodontics, SDM College of Dental Sciences, is an example of that cumulated experience and wisdom. The book is the worthy successor to Professor Rao's first book entitled the *Diagnostic Methods in Endodontics*, sharing his extensive experience in teaching, research and patient care.

The word Endodontics is derived from the Greek words *endo* meaning inside and *odons* meaning tooth (inside the tooth). And Endodontology is the study of the form, function, health and diseases of the dental pulp and periradicular tissues, their prevention and clinical management. Root canal treatment is the procedure used by endodontics to save a tooth that would otherwise be removed due to pulpal infection and disease. During the past decade there have been unprecedented advances in the understanding of the biological basis of the disease and the technology to deal with it clinically. The *Advanced Endodontics* is a valiant attempt to consolidate the principles and practice of endodontics for the benefit of dental students and teachers in the country.

PNR Nair, DVM PhD

Research Professor
Department of Restorative Dentistry and Endodontology
University of Connecticut Health Centre
Farmington, Connecticut, USA

Visiting Professor
Eastman Dental Institute
University College London
London, UK

Preface

Endodontics is a branch of dentistry that deals with the tooth pulp and its diseases. It is gaining importance due to patients's increasing awareness of dental health, prevention, saving teeth and oral hygiene. There is a demand for a painless alternative to extraction to save the teeth and this alternative is root canal therapy. The 21st-century endodontics with all its advancements is on the way to solve the existing numerous difficulties. The ultimate goal of modern endodontics is to effectively shape the root canals to facilitate thorough cleaning of entire system with less time consumption leading to easy and effective obturation.

Advanced Endodontics is meant mainly for postgraduate students. It includes the most recent developments in the field of endodontics.

From diagnosis to periapical surgery, there have been significant changes, both in concept and equipment. Recently, tissue engineering has been used to revitalize dentin and pulp tissue.

In modern practice, proper diagnosis is the key for the success of endodontic treatment. This starts with a good relevant case history, clinical examination and diagnostic tests, which form an indispensable part of diagnostic system. The new methods of assessing pulp vitality like Laser Doppler flowmetry, Infrared thermographic imaging, pulse oxymetry, liquid crystal testing and Hughes probe eye camera are presently experimental and mainly research oriented and are expected to be clinical tests in the forthcoming days. Digital radiography and electronic apex locators have also revolutionized clinical endodontics. DNA and RNA based microbiological techniques to detect uncultivable microorganisms, i.e. Polymerase chain reaction and Microarray technology are used to identify and study a large array of genes. A relationship between clinical symptoms and inflammatory molecules has been demonstrated reporting the significance of substance 'P'.

"Access is success" should always be borne in mind during endodontic treatment. A detailed knowledge of pulp chamber and root canal anatomy is required for success of endodontic treatment. There are various methods to determine exact working length including radiographic method and apex locators. Digital radiography has also revolutionized the clinical endodontics A film less technique commercially developed to reduce radiation exposure, is used to 'digitalize' the image that can be analyzed, measured and manipulated. Recently use of apex locators is considered to be the advanced method to determine the working length. First generation apex locators had disadvantages which have been overcome now by using third and fourth generation apex locators. These are reported to be very accurate in the determination of working length.

One of the key advancement in endodontic practice is operating microscope. It provides magnification and illumination and is useful for locating the canals after the access is made, and is necessary to address anatomical complexities and procedural complications associated with difficult cases. Enhanced vision, coaxial lighting and improved optics helps in identifying miniature canal openings, remnant pulp tissue and incipient fracture lines. The introduction of endoscopes at the turn of millennium involves using a fiberoptic probe to explore internal and external components of root canal aiding clinician in diagnosis and also to communicate and educate the patient.

The cleaning and shaping of the canal is one of the important preliminary requisite for endodontic treatment. There are various changes made in the endodontics instrument material and design. Nickel titanium (NiTi) files have become a mainstay in most endodontic procedures. Because of their property of shape memory and superelasticity, these files can be effectively used in curved canals for debridement. Varying the taper of the instrument leads to a more efficient preparation of root canal space. While biomechanical preparation can reduce the bacterial count significantly; mechanical debridement does not disinfect root canal system completely. Thus, a root canal irrigant is needed to aid in the debridement. Various techniques and irrigating solutions are currently used to attain disinfection. Recently MTAD has been introduced as a final rinse for disinfection of root canal system. This irrigant is able to remove the smear layer safely, and it is more effective disinfectant than NaOCl even against resistant bacteria such as *Enterococcus faecalis.*

After proper cleaning and shaping and disinfection of root canal system, proper obturation of the canal is necessary to prevent reinfection. Different techniques of gutta-percha compaction have undergone various modifications in their insertion and compaction techniques. In older days torch or open flame was used to seal or melt the gutta-percha. This technique is now called "Flintstone" age endodontics.The system B and Touch-n-Heat allows a safer means to heat the gutta-percha. Delivery systems like Obutra II and solid core carriers like Thermafil and Simplifil have become a necessity in modern endodontic practice.

Ultrasonic devices have become essential tools for cleaning the isthmus after access preparation, assisting the removal of posts and separated instrument, root end preparation during surgical treatment of root canals, and searching for the calcified canals.

Lasers have various applications in endodontics such as measuring pulp vitality, preparing and disinfecting root canals and performing endodontic surgery. These devices offer a thin fiberoptic delivery system entering narrow root canals. Other applications of lasers include hemostasis, sterilization of root canals and smear layer and debris removal and even gutta-percha removal.

In spite of advancements in modern endodontic technology there are certain problems that may occur during or after treatment. Most common problems are broken instruments and perforations. Many kits have evolved for the removal of broken instruments from the canal like Masserian kit; Ruddles instrument removal system, etc., Management of perforations in the older times was done using calcium hydroxide, zinc oxide, and GIC during treatment or retreatment. Recently the advent of new material MTA (Mineral trioxide aggregate) has revolutionized endodontics. MTA has been used successfully in the repair of lateral root perforations and furcal perforations, vital pulp capping agent, apical plug in one visit apexification and as a root-end filling material and also as a coronal sealing material. A variety of new retrograde filling materials can be used which includes Super EBA, IRM, and Dentin bonding agents and most recently MTA and VERRM.

The science of endodontics has undergone significant changes which have resulted in improved treatment outcomes and an opportunity to preserve the natural dentition. These objectives can be achieved with less morbidity and more predictability. Compilation of more current clinical data that are based on procedures performed with more advanced techniques will provide a more accurate rate of healing after non-surgical and surgical endodontic therapy. The future holds the promise of continued growth of research knowledge and systematic reviews which will provide most valuable evidence connecting the patient, the clinician, the policy maker, the benefit purchaser and benefit provider in the decision-making process.

Endodontics is growing with rapidly changing treatment modalities in accordance with advancements in the technology leading to the precision in treatment outcome. No other branch in dentistry is changing at this rate. Procedures from access cavity preparation, Microscopes, Apex locators, Rotary instrument systems, Obturating systems and Surgical endodontics to tissue engineering have changed to an extent to appreciate the results clinically. The book in the form of *Advanced Endodontics* is the contribution of my vast experience to the profession.

In this regard I am extremely grateful to our Principal Dr C Bhasker Rao, who encouraged me throughout my career. I would like to thank Dr PNR Nair BVSc, DVM, PhD, Senior Scientist, Department of Oral and Structural Biology, Center of Dental and Oral Medicine, University of Zurich, Switzerland, who wrote the foreword of this book and has given me valuable suggestions.

My immense thanks to Dr Priya Horatti, Professor Department of Conservative and Endodontics for her contribution in this book. I would also like to thank all staff members of Conservative Department. It is my pleasure to acknowledge Dr Manjunatha RK postgraduate student who helped me in bringing out this book, and also all postgraduate students in the department of Conservative for their constant feedback and support.

It is my privilege to thank **M/s Jaypee Brothers Medical Publishers (P) Ltd** to bring this book for final shape.

I would like to thank Pujyashree Veerendra Heggade, President SDME Society for encouraging me to bring out this book. I would like to thank Mrs Suvarna SK, Computer Operator for helping in graphics and other book work.

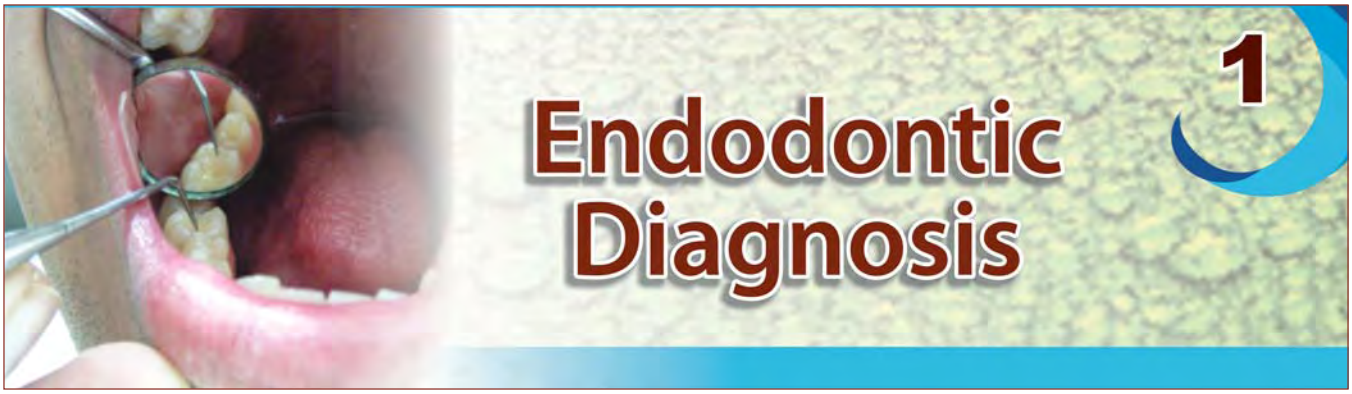
Last but not the least, I would like to thank each and every person who has in some way or the other helped me.

R Nageswar Rao

Contents

1. Endodontic Diagnosis 1
2. Pulpal and Periradicular Diseases 29
3. Endodontic Emergencies 46
4. Rationale of Endodontic Treatment 55
5. Oral Microflora and Culture Media 61
6. Principles of Endodontics 79
7. Local Anesthesia 92
8. Pulp Therapy 97
9. Root Canal Morphology and Access Cavity Preparation 105
10. Working Length Determination 115
11. Irrigating Solutions 133
12. Biomechanical Preparation 141
13. Intracanal Medicaments 180
14. Root Canal Sealers 186
15. Obturation 198
16. Importance of Coronal Sealing 222
17. Post-endodontic Restoration 226
18. Endodontic Microsurgery 256
19. Traumatic Injuries to the Teeth 288
20. Resorption 301
21. Bleaching 307
22. Lasers in Endodontics 326
23. Endodontic Implants 335
24. Tissue Engineering in Endodontics 337
25. Endodontic Failures and Management 341
26. Nanodentistry 353
27. Summary and Conclusion 357

Index *359*



DIAGNOSTIC METHODS IN ENDODONTICS

Diagnosis is a process of determining the nature of a disease. Correct diagnosis is very important for proper treatment.

Differential diagnosis is the process of differentiating between similar diseases. For correct differential diagnosis, proper knowledge of the disease, skill and art on how to apply proper diagnostic method is required.

Diagnosis begins with careful questioning, with regard to patient compliance. In most cases it may require a careful examination of the patient and necessary laboratory tests. To come to a correct diagnosis one should properly correlate the symptoms and laboratory result.

Symptom is a physical or mental phenomenon, circumstance or change of condition arising from and accompanying a disorder and constitutes evidence. Symptoms as stated by Grossman, are phenomenon or signs of a departure from the normal, and are indicative of an illness. The symptoms elicited are further divided as:

1. Subjective symptoms
2. Objective symptoms

1. Subjective symptoms are those, which are experienced and reported to the clinician by the patient.
2. Objective symptoms are those, which are obtained by the clinician through various tests.

It thus follows that corners or pillars of a correct clinical diagnosis are:

A. Good case history
B. A thorough clinical examination and
C. Relevant investigations/diagnostic tests

The above mentioned factors are then interpreted in the light of the clinician's knowledge and experience. In order to obtain a good case history, record of substantial data with relation to the patient's medical and dental history is of great importance.

MEDICAL HISTORY

Although there hardly exists any systemic condition, which would contraindicate endodontic therapy (except conditions like uncontrolled diabetes or a very recent myocardial infarction), a comprehensive medical history of the patient is necessary. Such a medical history would aid the dental clinician in deciding whether a prior medical consultation or premedication (chemoprophylaxis) would be required, before the diagnostic examination or regular dental therapy is begun.

DENTAL HISTORY

The primary aim in recording the patient's dental history is to obtain a complete informative data of the patient's chief complaint. Most common reasons which patients elucidate as chief complaints range from pain and swelling to loss of function or aesthetics. Whatever the reason, the patients chief complaint is the best starting point for a correct diagnosis. As mentioned. PAIN, is one of the most common chief complaints encountered. It is, therefore, imperative to have a detailed understanding of this most commonly encountered chief complaint.

PAIN

When patients present with a history of pain, careful attention given to their description and their answers

to questioning, will often assist in a provisional diagnosis to be made. In order to attain a detailed knowledge regarding pain, following questions may be necessary:

Type of Pain

Grossman has stated pulpal pain to be of the following two varieties viz:

a. Sharp, piercing and lancinating—a painful response usually associated with the excitation of the A-nerve fibers. This pain usually reflects REVERSIBLE state of pulpitis.
b. Dull, boring, gnawing and excruciating—a painful response usually associated with the excitation of C-nerve fibers. This pain usually reflects an IRREVERSIBLE state of pulpitis.

Duration of Pain

When the pain is of a shorter duration (1 minute), it is considered to be reversible pulpitis, whereas when the pain is of a longer duration, it is considered to be irreversible pulpitis. Clinical experience has shown that a tooth with pulpal pain that disappears on removal of the irritant has shown an excellent chance of recovery without the need for endodontic treatment.

Localization of Pain

- Sharp piercing pain can usually be localized and respond to cold.
- Dull pain usually referred/spread over a larger area responds more abnormally to heat.
- Patient may report that their dental pain is exacerbated while lying down or bending over. This occurs because of the increase in blood pressure to the head, which therefore increases the pressure on the confined pulp.

Factors which Provoke/relieve Pain

On assessment of pulp vitality by AH Rowe et al (According to an article in Int Endo J 1990), response to a provoking factor (e.g. on mastication) indicates pulp vitality, but stimulation causing extended severe pain suggests irreversible pulpitis.

Thus, pain which is recorded as the complaint, is considered to conclude an acute or chronic, reversible or irreversible condition of the pulp.

Acute reversible pulpitis is characterized by pain which is of a:

- Short duration
- Localized
- May be piercing/lancinating in nature
- More responsive to cold than heat
- Caused by a specific irritant and disappears as soon as it is removed.

On the contrary:

- Abnormal dental pain, which responds to heat,
- Which occurs on changing the position of the head, awakening the patient from sleep, and
- Dull pain of longer duration, which occurs during mastication in a carious exposed tooth, are symptoms of irreversible pulpitis.

BASIC CONSIDERATIONS—CLINICAL EXAMINATIONS

This phase can be divided as:

A. Extraoral examination
B. Intraoral examination

The inspection phase of the extraoral and intraoral clinical examination should be performed in a systematic manner.

Extraoral Examination

The extraoral clinical examination begins with a patient's dental history. While talking to the patient, the clinician should look for facial asymmetry or distensions, which would indicate a swelling of odontogenic origin or a systemic ailment.

When the patient enters the dental clinic, the dentist carefully looks at the external appearance to look for facial asymmetry, distensions or discomfort, which would indicate inflammatory changes originating intraorally and observable exteriorly, indicating a serious underlying lesion. Extraorally the dentist should look for facial asymmetry (if any), or for localized swelling, lymphadenopathy (Fig. 1.1), changes in color, bruises, scars, similar signs of disease, trauma or of any previous treatment.

Intraoral Examination

This begins with a general evaluation of the oral structures, while the occlusion is checked (for any derangements if any), the lips, cheeks, vestibules and

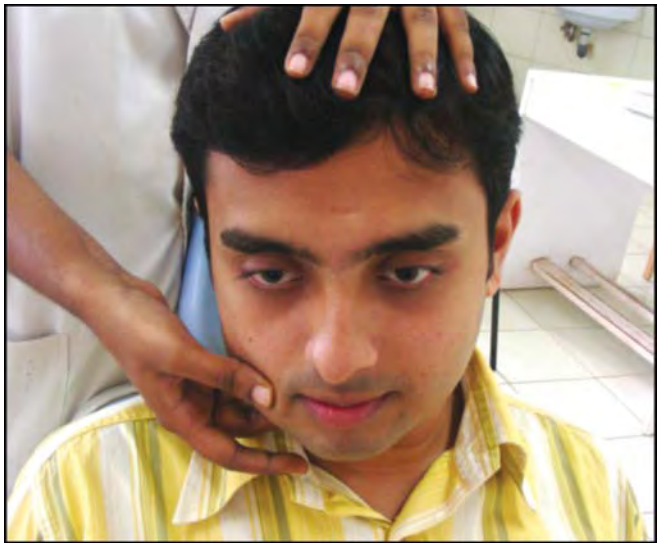


Fig. 1.1: Extraoral examination—lymph node palpation

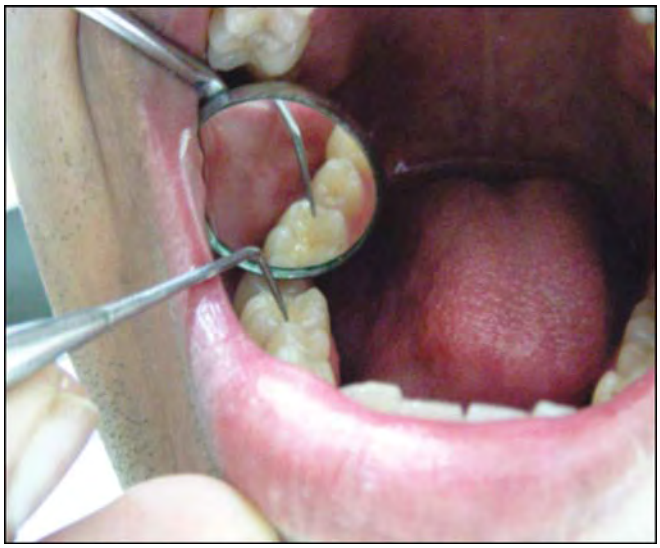


Fig. 1.2: Intraoral examination

mucosa are examined for any evident abnormalities. Several tests have been stated in order to determine the condition of teeth and supporting structures (Fig. 1.2).

Commonly used methods of endodontics diagnosis:

1. Visual and tactile inspection
2. Percussion
3. Palpation
4. Mobility and depressibility tests
5. Periodontal tests
6. Thermal tests
7. Anesthetic tests
8. Test cavity
9. Transillumination
10. Biting
11. Staining
12. Gutta-percha point tracing
13. Electric pulp testing
14. Radiographs

RECENT METHODS OF ENDODONTIC DIAGNOSIS

Thermal Devices

- Heat stimulation by laser instead of hot gutta-percha

Electric Devices

- Electric pulp testers (EPT)

Blood Flow Determination Devices

- Laser Doppler flowmetry (LDF)
- Pulse oximeters
- Transmitted-light photoplethysmography
- Dual wavelength spectrophotometry (DWLS)

Surface Temperature Measurement Devices

- Liquid crystal testing
- Hughes probeye camera/infrared thermography
- Electronic thermography

Transillumination Devices

- Fiberoptic transillumination.
- Orascopy/endoscopy

Imaging Techniques

- Xeroradiography
- Digital radiography (RVG)
- Digital subtraction radiography
- Ultrasonography (echography).
- Computerized tomography (CT)
- Tuned aperture computed tomography (TACT)
- Magnetic resonance imaging (MRI)
- Xenon-133 with radiolabeled microspheres

Miscellaneous

- Detection of interleukin-1 beta in human periapical lesion.
- Computerized expert system

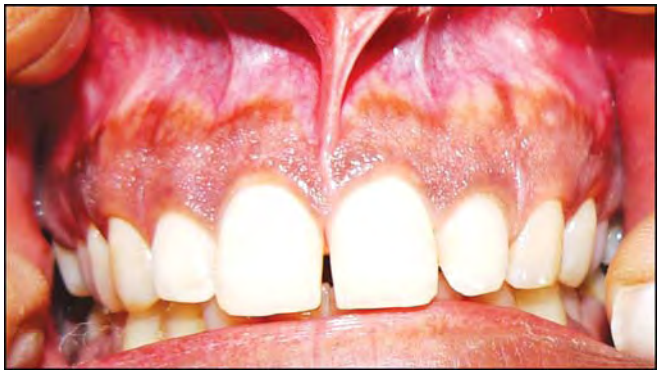


Fig. 1.3: Normal gingiva

Visual and Tactile Inspection

This is one of the simplest and the easiest of the diagnostic tests performed by the clinician.

It is done casually during examination and as result much essential information is lost inadvertently. Grossman has stated that the prime objective of visual and tactile inspection is evaluation of the '3C's' : Color, Contour and Consistency of hard and soft tissues.

Soft Tissue

Color—The normal color of gingiva is pink (coral pink to be precise). Change from this is easily visualized in inflammatory conditions (Fig. 1.3).

Contour—Change in normal contour (e.g. of scalloped gingiva) occurs with a swelling.

Consistency—On inspection gingiva appears healthy, firm, resilient, while a soft, fluctuant or spongy tissue is more indicative of a pathological state (Figs 1.4A and B).

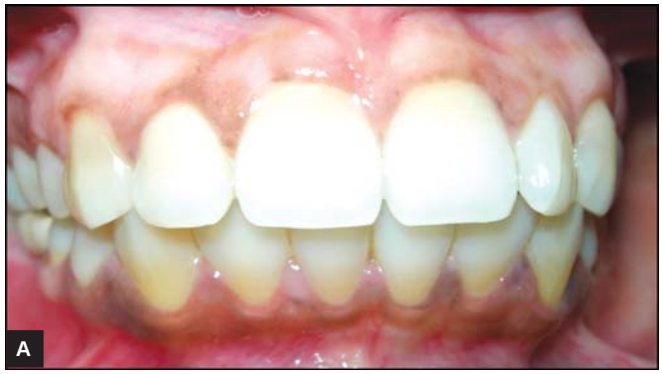
Hard Tissue

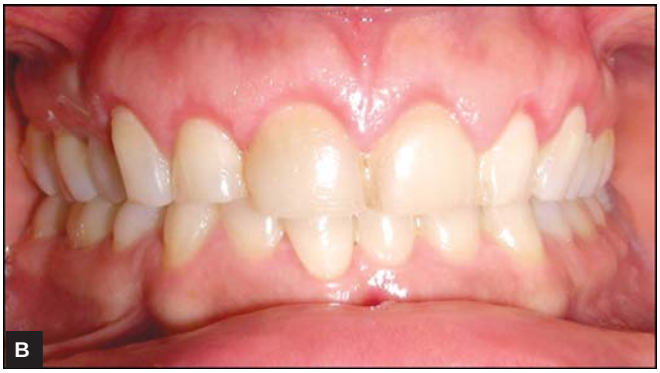
A similar parameter of the visual and tactile inspection, i.e., of the 'C's' employed for the dental tissues as well.

Color—Normal teeth show life like translucency and sparkle that is missing in pulpless teeth which appear more or less opaque (Fig. 1.5).

Note: This discoloration however could be due to a variety of other reasons like old amalgam restorations, tetracycline stains, etc.

Contour—This examination should also include the visualization of contours of affected teeth, such as fractured teeth, wear facets, improperly contoured restorations, or altered crown contours as these factors can have a marked effect on the respective pulps (Fig. 1.6).





Figs 1.4A and B: Photograph showing mild gingival inflammation with loss of stippling

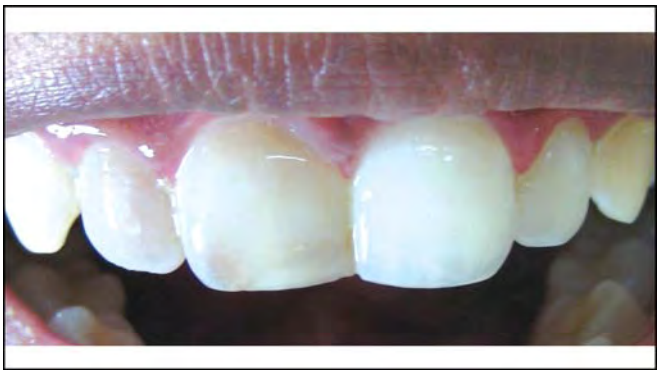


Fig. 1.5: Loss of normal translucency in pulpless tooth

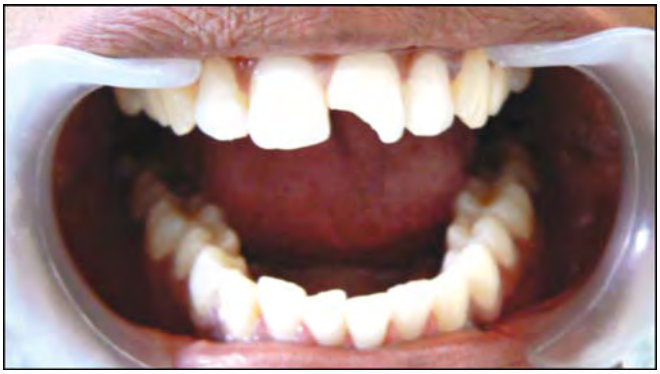


Fig. 1.6: Altered contour as a result of fracture

Consistency—Change in the consistency of hard dental tissues is related to the presence of caries, external and internal resorption.

The visual and tactile inspection is usually carried out with a mouth mirror, explorer and a periodontal probe under dry conditions with good illumination source (Fig. 1.2)

The teeth and soft tissues adjacent to the involved tooth must also be examined for detection of any related swelling and pathologic conditions.

Presence of a sinus opening into the gingival crevice and deep pockets are usually discovered with the use of the periodontal probes. Their presence aids in concluding the final prognosis of the involved teeth.

General visual examinations of the entire mouth should be made to ascertain whether the tooth requiring treatment is a strategic tooth.

Percussion (Fig. 1.7)

The technique employed for percussion is relatively simple.

Before percussion of the involved tooth, instructions are to be given to the patient to raise his/her hand or make an audible sound in order to let the clinician know when the patient feels painful. i.e. "TENDER", or "DIFFERENT" on percussion.

Technique

Before percussion of the teeth with the handle of the instrument (a mouth mirror etc.), the quadrant of the involved tooth is percussed using the index finger with quick blows of low intensity. The teeth should be tapped (with the index finger) in a random fashion so that the patient cannot "anticipate" when the tooth will be percussed.

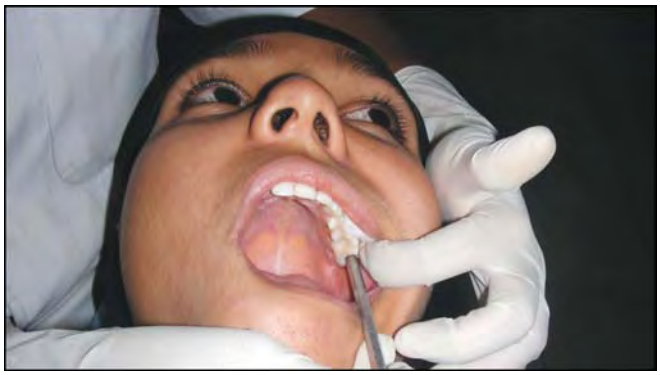


Fig. 1.7: Percussion test

When no response is elicited on digital percussion, the handle of an instrument is to be used. Percussion is done in both vertical and horizontal directions. Change the sequence of percussion in successive tests to eliminate bias.

The force of percussion should only be strong enough for the patient to differentiate between a sound tooth and a tooth with inflamed periodontal ligament. The clinician can use the chief compliant and dental history as a guideline in deciding on how strongly to percuss the teeth.

The force of percussion is one of the skills that the clinician should develop as a part of the "ART" of endodontic diagnosis. The proprioceptive fibers in an inflamed periodontal ligament will, when percussed, help the patient and the clinician locate the source of pain.

Response to Percussion

Positive response to percussion is indicative of periodontitis (Pericementitis) which could be due to:

i. Teeth undergoing rapid orthodontic movement.
ii. High points in recent restorations
iii. Lateral periodontal abscess
iv. Partial/ total pulpal necrosis

Negative response to percussion may be seen in case of:

i. *Chronic periapical inflammation*—it has been stated that percussion sounds offer diagnostic clues.
ii. *Dull note*—signifies abscess formation
iii. *Sharp note*—denotes inflammation

This test reveals the presence or absence of inflammation of the periodontium, i.e. it provides us with a report on the status of the periodontium. It is also important for the clinician to keep in mind that this test does not give any indication regarding the health or integrity of the pulp tissue. In conjunction with other tests viz., palpation, mobility and depressibility, it indicates the presence or absence of periodontitis, which by itself is not an indication of irreversible pulpitis or pulp necrosis.

Palpation (Fig. 1.8)

Among the simplest of the diagnostic tests to be conducted, palpation employs the usage of the (index finger) fingertip, supplemented with a light digital

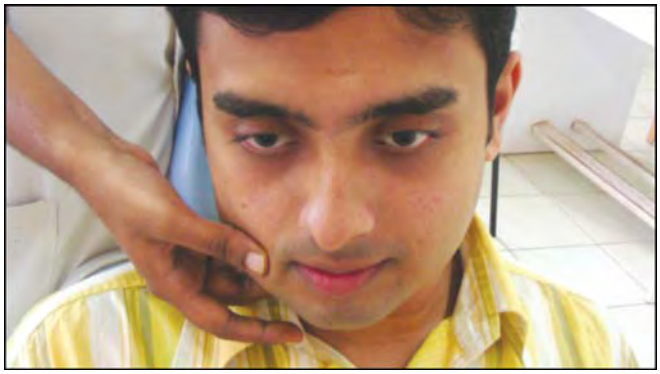


Fig. 1.8: Palpation test

pressure to examine tissue consistency and pain response.

The importance of this test other than as an aid in locating the swelling an involved tooth is in determining the following:

i. Whether the tissue is fluctuant and enlarged sufficiently for incision and drainage.
ii. The presence, intensity and location of pain.
iii. The presence and location of adenopathy. In palpating for enlarged lymph nodes, exercise caution to avoid spread of infection through lymphatic system in acute infectious conditions.
   - When posterior teeth are infected - Submaxillary lymph nodes and Submandibular lymph nodes are involved.
   - When lower anterior teeth are infected - Submental lymph nodes are involved. Even the cervical lymph nodes should be palpated.
iv. The presence of bony crepitus.

Mobility and Depressibility Tests

The rationale of mobility test is to evaluate the integrity of the attachment apparatus surrounding the tooth.

- The test essentially consists of moving the involved tooth laterally in the socket using handless of two instruments or more preferably using two index fingers. The observed mobility could then be graded as per classifications provided by Grossman, Cohen, and Miller.
- The test for depressibility is similar and is performed by applying pressure in an apical direction on the occlusal/incisal aspect of tooth and observing vertical movement.

Grades of Mobility (Grossman and Cohen)

- *Grade I (First degree)*—Noticeable/barely discernable movement of the teeth within its sockets.
- *Grade II (Second degree)*—Lateral/horizontal mobility within a range of 1 mm or less
- *Grade III (Third degree)*—Movement greater than 1 mm or when the tooth can be depressed into the socket.

Grades of Mobility (Miller)

0 - Nonmobile/mobility within physiologic limits.
1 - Mobility within range of 0-0.5 mm.
2 - Mobility within range of 0.5-1.5 mm with lateral movements.
3 - Mobility more than 1.5 mm with lateral movements and can be intruded /depressed into the socket.

Mobilometers

These are electric devices/ gadgets, which aid in determining tooth mobility.

The apparatus essentially consists of two electrodes/prongs which hold the facial and lingual surface of the teeth. The degree of mobility tested is then reflected as a numerical reading either on the instrument itself or on an attached computer screen.

Periodontal Examination (Fig. 1.9)

No clinical examination is complete without careful evaluation of the tooth's periodontal support. Multirooted teeth should be carefully probed to determine whether there is any evidence of furcation involvement.

A lateral canal exposed to the oral cavity through a periodontal disease may become the portal of entry

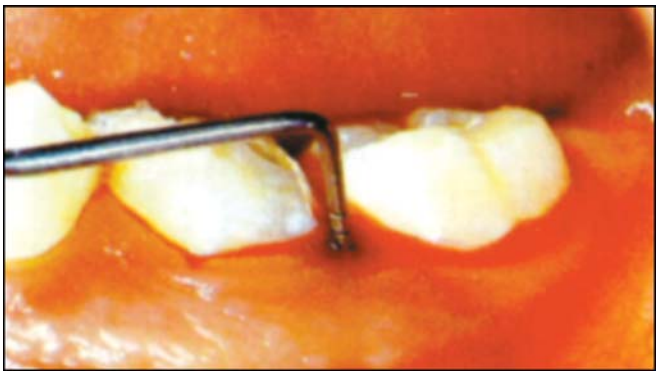


Fig. 1.9: Periodontal examination

for toxins, which may cause pulpal degeneration. Thermal and electric pulp tests must be performed along with periodontal examination to distinguish between disease of pulpal and periodontal origin.

Thermal Tests

These tests are performed mainly to assess the state of the pulp. The thermal tests performed are:

1. Heat test and
2. Cold test

Although both are tests performed to determine pulpal response and sensitivity they are conducted for different diagnostic reasons.

Grossman has stated that a response to cold reflects a vital pulp regardless of whether it is normal or abnormal. A heat test does not confirm vitality. An abnormal response to a heat test however exhibits presence of a pulpal or periapical disorder requiring endodontic treatment.

Another diagnostic difference as pointed out by Grossman between the heat and cold tests is that, when a reaction to cold occurs the patient can quickly point out to the painful tooth, unlike in a heat test situation where the response could be localized, diffused or even referred to a different site. The results of thermal test should be thus co-related with other tests conducted to ensure validity.

Technique Employed for Thermal Tests

Prior to performing these tests, it is important for the clinician to explain the manner and procedure of the tests to the patient and also the kind of sensation he/ she may experience. It is also important for the clinician to perform the same tests first on teeth, which are to be used as controls [contralateral teeth can be used as controls.

The use of these contralateral teeth as controls in performing thermal tests is two fold:

i. It guides the clinician to evaluate the difference in response, the affected tooth provides.
ii. It helps the patient understand better the nature of the stimulus he/ she would experience.

The heat/cold (even EPT) tests are performed by placing the stimuli on the Inciso-Labial (anterior) surface or the Occluso-Buccal (posterior) surface.

However, while performing these tests (and also the EPT which will be discussed next) exposed dentinal surfaces and restored surfaces should be avoided. The exposed dentinal surface would provide an exaggerated response. The response of dentin to the heat and cold tests according to AH Rowe and TR Pittford is based on the Hydrodynamic Theory as postulated by Brannstrom (1963).

As far as restored surfaces are concerned, Non-metallic restorations are relatively poor conductors and a test made through such materials would provide a delayed response or no response at all. Metallic restorations being good conductors may result in responses at low levels of stimulation and may also cause misleading results by conducting the stimulus to an adjoining metallic restoration in an adjacent tooth, an effect which may be reduced by the insertion of a celluloid strip between the teeth.

Clinical technique for heat and cold tests is as follows. Initially, the teeth in the quadrant must first be isolated and then dried with 2 × 2 inch gauge and a saliva ejector placed. Cohen states that the teeth prior to conducting these tests should not be dried with a blast of air because the room temperature air may cause a thermal shock and also saliva may be sprayed onto the clinician/ assistant.

Heat Test

As previously mentioned, isolation of the quadrant to be tested is done; the heat test can be performed using different techniques, which deliver different degrees of temperature.

The preferred temperature, however, for performing a heat test (according to Cohen) is 65.5°C or 15°F.

This test may produce a temperature as high as 150 degrees centigrade at the surface of the tooth. According to AH Rowe et al [INT END J 1990 V-23] temperature up to 150°C is necessary for conducting thermal tests on teeth. Teeth are first coated with Vaseline to avoid guttapercha sticking to the tooth.

For the heat test, contrary to Cohen's belief of avoiding warm air, Grossman employs the use of warm air against the exposed surface of the tooth to determine the patients initial response, if any, to thermal stimuli.

The heat test can be performed using different techniques such as:

1. Hot air
2. Hot water
3. A hot burnisher
4. Hot gutta-percha

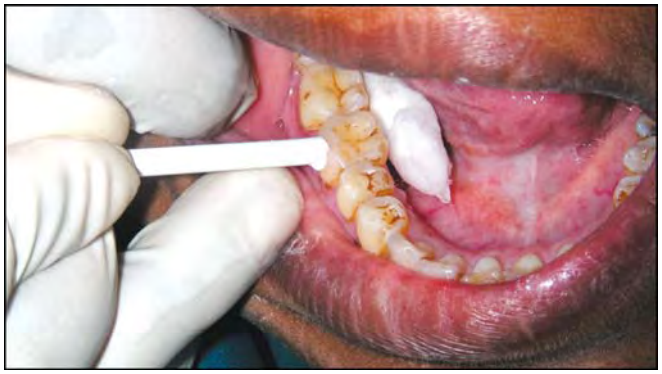


Fig. 1.10: Heat test with heated gutta-percha stick

5. Hot compound.
6. Polishing of crown with a rubber cup.
7. Lasers (Recent methods).

Any instrument that can deliver controlled temperature to the tooth can be used.

The common method employed is the one with gutta-percha stick. The gutta-percha stick is heated over an alcohol flame until it becomes shiny and soft. The heated end is then immediately placed on the tooth surface (i.e. incisolabial for anterior and occlusobuccal of posteriors) (Fig. 1.10).

Care should be taken not to place an overheated gutta percha stick (seen clinically as "smoking") or prolonged application of the stick as it may cause a burn lesion in an otherwise normal pulp (Cohen).

In cases of teeth with full or partial (as in PFM) metal coverage, the blade of a wax instrument may be heated for 5-10 seconds in an alcohol flame and placed on the metal surface. Also in cases of full metallic restorations, like full crowns, heat test can be done by "polishing" the metal crown with an abrasive wheel/ disc at a low speed (on the angle surface-Cohen).

A different technique is employed for a heat test with hot water. Here the tooth to be tested is isolated using a rubber dam and immersed in "coffee hot" water delivered from a syringe.

The disadvantage of this test is that the response noted is limited to only the tooth which is tested.

In case of crowns , warm water is preferred.

The heat test is commonly used for the differential diagnosis of pulp status. Using lasers for heating gutta-percha is more precise method than ordinary method of heating gutta-percha. The disadvantage of this method is pain response cannot always be obtained because of the thick enamel and dentin or the high threshold of dental pulp. The laser stimulation method by using pulsed Nd: YAG laser was reported as an alternative to the hot gutta-percha method. The pain induced by the pulsed Nd: YAG laser was reported to be mild and tolerable compared with the pain induced by the conventional electric pulp tester. In addition to the pulsed Nd: YAG laser, other lasers may be used to diagnose the difference between vital and nonvital pulp in future.

When normal pulp is stimulated by the LASER, pain is elicited immediately and disappears once the source is removed whereas in acute pulpitis pain continues for more time after stopping the laser stimulation.

Lasers when used for diagnosis can differentiate normal pulp, acute pulpitis, advanced irreversible pulpitis (serous pulpitis) and acute irreversible pulpitis which presents as necrosis.

Cold Test

The technique for the cold test begins by isolating the quadrant with the tooth to be tested.

Cold application can be performed in any of the following ways viz.,

- A stream of cold air from a 3-way syringe directed against the crown of previously dried tooth.
- Use of ethyl chloride spray (which evaporates rapidly) absorbing heat and cooling the tooth surface.
- Application of ice (Fig. 1.11).
- Application of Carbon dioxide snow (dry ice) described by Ehrmann.

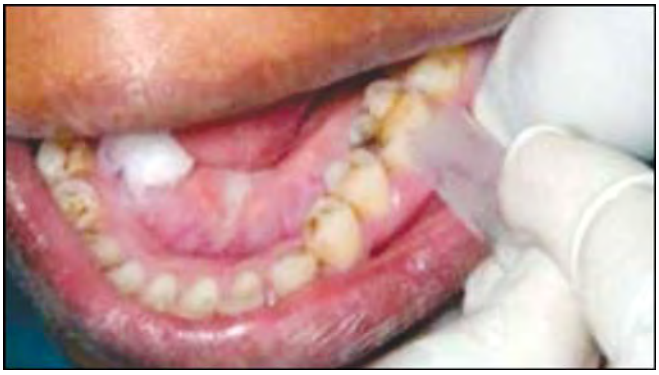


Fig. 1.11: Cold test with ice stick

The temperature of dry ice is -78 degrees centigrade and thus with this temperature one is able to penetrate full coverage restorations and therefore elicit a reaction in the underlying tooth to cold.

The reaction of pulp to application of dry ice method has been studied by Dowden and Co., who applied dry ice at -78 degrees centigrade for 1-3 mins to teeth in monkeys. Results showed an initial pulpal injury which later recovered. Also, Ausberger and Pewters (1981) concluded in their studies that, application of carbon dioxide snow produces a low intrapulpal pressure and is far more effective and reliable even in immature teeth.

The disadvantage with the carbon dioxide snow is that it may cause craze lines in the enamel.

Thus, an aerosol of dichloro-difluoromethane was introduced, to substitute the carbon dioxide snow, which was claimed to be as effective as Carbondioxide snow and less likely to produce enamel changes.

Responses to Thermal Tests

The patient's response to heat and cold tests are identical because the neural fibers in the pulp transmit only the sensation of pain (Hydrodynamic theory - Brannstorm). There are four possible reactions, that the patient may experience,

i. No response—may be non vital or vital but giving a false-negative response due to excessive calcifications, immature apex, recent trauma, patient medication, etc.
ii. Painful response—which subsides when stimulus is removed from the tooth—reversible pulpitis.
iii. Moderate, transient response—normal.
iv. Painful response, which lingers after removal of stimulus—irreversible pulpitis.

Note: Modification of techniques for thermal tests:

A modified technique for thermal tests is provided by the Analytic Technology pulp tester, which has a hot probe tip and a cold probe tip. The heating of the hot probe tip and cooling of the cold probe tip are controlled separately by the membrane switches on the control panel.

Anesthetic Test

This test is restricted to patients who are in pain at the time of the test and when the usual tests have failed to help identify or localize the offending tooth.

The objective is to anesthetize a single tooth at a time until the pain disappears and is localized to specific tooth.

The technique is as follows:

- Using infiltration or intraligmentary injection, inject the posterior most tooth in the suspected zone. If pain still persists after tooth has been completely anesthetized then anesthetize the next tooth mesial to it and continue to do so until the pain disappears.
- If the source of pain cannot be differentiated, i.e. maxillary / mandibular) then mandibular block (i.e. an inferior alveolar nerve block) is implemented.
- Cessation of pain after administration of the mandibular block would naturally indicate the involvement of mandibular tooth and further localization of the affected tooth is done by an intraligamentary injection once the effect of block wears off. The anesthetic test, quite understandably is performed as one of the last resorts in localizing the offending tooth.
- It is however advantageous in relation to the "Test cavity" during which iatrogenic damage is possible.

Test Cavity

This is a last resort test to be conducted to evaluate the pulp vitality and is performed when other diagnostic methods have failed.

The cavity is prepared by drilling through the dentino-enamel junction of an unanesthetized tooth at a slow speed and without a water coolant.

Sensitivity and pain elicited by the patient is an indication of the pulp vitality. Sedative cement is then placed in the prepared cavity and the search for the cause of pain may be continued.

On the contrary, if no pain/ sensitivity is recorded. The cavity preparation may be continued until the pulp chamber is reached and if the pulp is noticed to be necrotic, routine endodontic treatment could be performed.

Electrical Devices

Electric Pulp Testers (Fig. 1.12)

Electric pulp tester (EPT) uses electric excitation to stimulate A- sensory fibers within the pulp.

The teeth to be tested must be isolated and dried with 2″ × 2″ gauze and the testing area must be kept

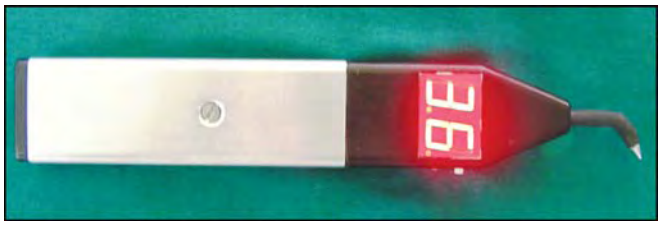


Fig. 1.12: Electric pulp tester

dry with saliva ejector to prevent false positive results caused by electric conduction to the adjacent tooth.

The operator must prepare the patient by explaining the diagnostic value of the test and the procedure that will be followed.

It is also important that the patient be informed about the sensations of heat and tingling felt during testing.

If the tooth has a proximal metallic restoration a rubber dam (or) celluloid strips should be placed inter proximally to prevent electrical conduction to the adjacent tooth. Since the clinician will be wearing non-conductive gloves, the patient will have to place a finger on the handle of the instrument to serve as a switch. The instrument will function only if the patient is touching the device, and any sensation will cease upon release, this reassures patients that they have control if any sensation occurs.

Pulp tester should be generously coated with a viscous conductor (e.g. tooth paste/electrode gel).

The electrode should be the applied to the dry enamel of the tooth being tested on the middle third of the facial surface of the crown. The current flow should be increased slowly to allow the patient time to respond before the attendant tingling sensation becomes painful. The electrode should not be applied to any restorations, because this could lead to false reading. If a positive reading is not obtained, the electrode should be applied to several different locations on the lingual and facial surfaces of the tooth to ensure that the negative reading is not the result of electrode placement (Fig. 1.13).

Each tooth should be tested at least two or more times and an average result should be recorded. The result may vary slightly with each test. However a significant variation in the response suggests a false reading.

Factors like enamel thickness influence the response time. The thinner enamel of anterior teeth

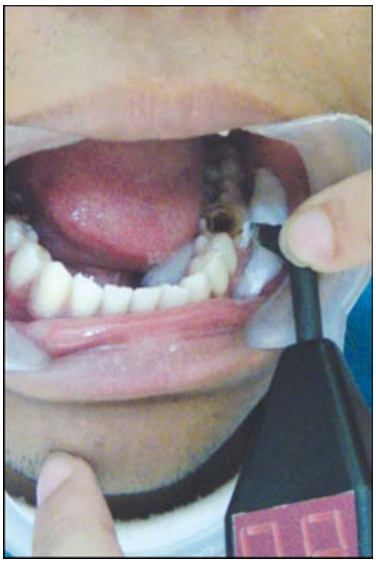


Fig. 1.13: Technique of application

yields faster response than does the thicker enamel of posterior teeth.

Advantages

- EPT is a useful way to determine the pulpal status of the tooth.
- In case of periapical radiolucency, EPT will help the clinician to determine whether the pulp is vital.
- Help differentiate pulpal disease from periodontal disease or non-odontogenic causes.

Disadvantages

- A positive response to electric pulp testing simply indicates that there are vital sensory fibers present with in the pulp. Many times, irreversibly inflamed pulp is responsive to EPT because it still contains vital nerve fibers that can produce a toothache.
- The EPT provides only a responsive or non-responsive result that correlates, in many cases, with vital or non-vital pulpal status. Therefore, attempting to interpret the numerical values produced by the EPT is not recommended.
- The EPT fails to provide any information about the vascular supply to the pulp, which is true determinant of pulp vitality
- "False positive response." Circumstances that can cause fake positive response include - patient's anxiety, saliva, and metallic restorations.
- "False negative response" means that although the pulp is vital, the patient does not indicate that any

sensation is felt. This can be due to premedication with drugs or alcohol, immature teeth, trauma, poor contact with tooth, inadequate media, and partial necrosis with vital pulp remaining in apical portion of root and Calcific metamorphosis. Therefore, it is essential to do multiple tests before a final diagnosis.

Blood Flow Determination Devices

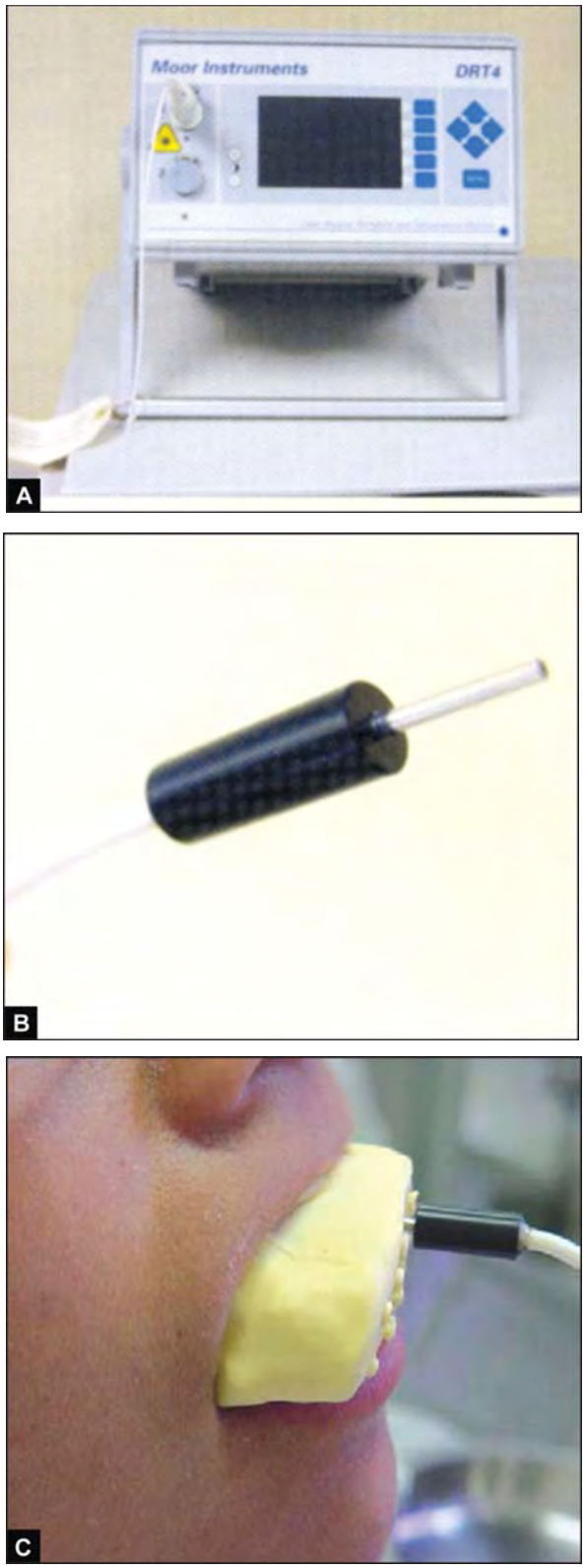
Diagnosis of Vitality of Dental Pulp Using Laser

Recent concept of evaluating the vitality of the pulp is based on the development of equipments that detect pulpal circulation. A traumatized tooth with normal blood supply, but severed sensory nerves makes the tooth non-responsive to stimulus. Development of sensitive devices will detect pulp blood components or blood flow in these situations which are demonstrated by detecting hemoglobin and its components, or pulsations in the pulp. These methods are not being used in clinical practice and are more of experimental orientation.

Laser Doppler Flowmetry (Figs 1.14A to C)

Any stimulus can initiate a neural response, whether it is physical contact, thermal change or electricity with the dentin and pulp. Electric pulp testers use electric current to stimulate the A delta neurons. When these fibers are intact, stimulations result in a painful sensation and the pulp is considered to be vital. However, intact nerve functioning is not essential for pulp vitality. Teeth with a history of recent trauma or the teeth in the area of orthognathic surgery can lose nerve supply in spite of an intact blood supply. A recently erupted tooth frequently gives a negative response; still the pulp will be vital.

To circumvent these limitations, newer testing modalities have been developed to determine the vascular supply of pulp thus indicating the vitality status of the tooth. Laser Doppler flowmetry uses Helium Neon (HeNe) and Gallium Aluminum (GaAlAs) as semiconductor diode lasers at a power of 1 or 2 mW. The wavelength of the HeNe laser is 632.8 nm and that of the semiconductor diode laser is 780 to 820 nm. To prevent laser beams from reflecting off the surrounding gingival, the measurement of the laser beams reflected from the dental pulp should be carried out under the rubber dam/custom fabricated



Figs 1.14A to C: (A) LDF unit (B) LDF probe (C) Probe with stent on the tooth

jig. The principle of determining the vitality status of dental pulp by laser Doppler flowmetry is based on the changes in red blood cell movements in the pulp tissue.

Mechanism of Action

Laser Doppler flowmetry uses a laser beam of known wavelength that is directed through the crown of the tooth to the blood vessels within the pulp. Moving red blood cells causes the frequency of the laser beam to be Doppler-shifted and some of the light to be back-scattered out of the tooth. This reflected light is detected by a photocell on the tooth surface, the output of which is proportional to the number and velocity of the blood cells.

Method of Use

The laser Doppler flowmetry is complicated by the fact that the laser beam must interact with the moving cells within the pulpal vasculature. To avoid artificial responses, a custom fabricated jig (i.e. mouth guard) is needed to hold the sensor motionless and maintain its contact with the tooth. The position on the crown of the tooth and the location of the pulp within the tooth cause variations in the pulpal blood flow measurements.

Advantages

- Allows painless diagnosis as compared to thermal and electric pulp tests.
- Useful for the vital or nonvital diagnosis of immature or traumatized teeth.
- For use in patients who are sensitive to tooth pain

Disadvantages

1. LDF probes detect only coronal pulpal blood flow and the results may not relate the actual blood flow on linear scale.
2. Positioning of beam on the crown of the tooth is difficult and necessitates the fabrication of jig.
3. Necessity for multiple probes for accurate assessment to compensate for inadequacies in calibration.
4. Hypertensive drugs and nicotine may affect blood flow to the pulp producing inaccurate results.
5. Cost of the equipment is too high for an average dental practice setup.
6. Reliability of the readings affected by signals from the gingival and periodontal tissue.
7. The readings are difficult to obtain in the teeth present in inaccessible areas and in cases where thickness of the enamel is more making the tool more predictable in anterior teeth.

The use of dual-probe laser Doppler flowmetry has been suggested to increase the reliability of this method. This LDF uses a 633-nm laser source.

Pulse Oximeter (Fig. 1.15)

Pulse oximeter offers a non-destructive, optical diagnostic method of monitoring pulp vitality by recording oxygenation of blood flow. This technique is being used in anesthesiology for recording blood oxygen saturation levels. Adaptation of pulse oximetry to the accurate diagnosis of the pulpal vitality is under investigation.

Principle: A pulse oximeter works on the principle that uses a photoelectric diode that transmits light in two wavelengths (Red - 660 nm, Infra red - 850 nm).

This light is received by a receptor as it passes through body parts. Difference between the light emitted and received is calculated by comparison of the ratio of the amplitudes of the transmitted infrared with red light and this information is used together with standard absorption curves using a microprocessor to provide pulse rate and oxygen concentration (Figs 1.16A and B)

Advantages

- It is a non-invasive, painless method for monitoring the pulp vitality.

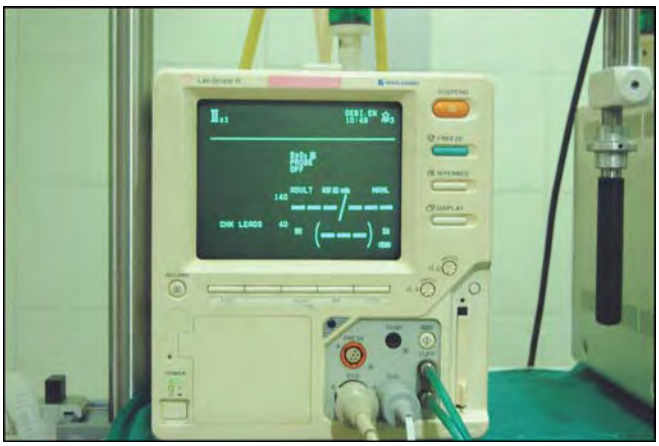
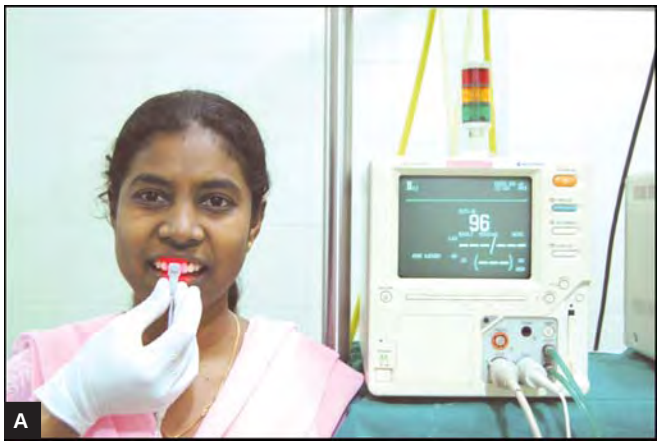
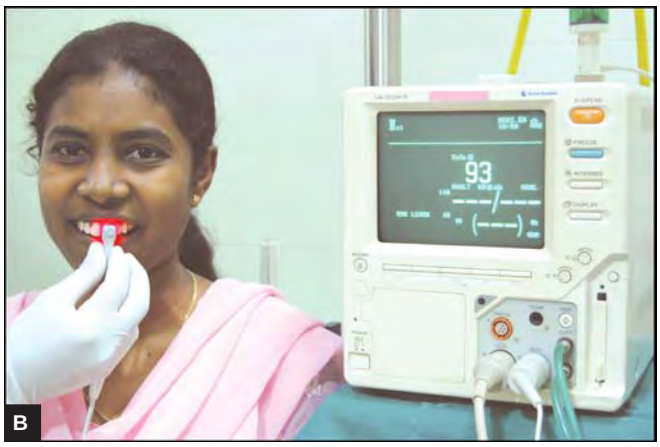


Fig. 1.15: Pulse oximeter





Figs 1.16A and B: Pulse oximeter showing oxygen concentration

- Pulse oximetry enables monitoring of the changes in oxygen saturation, thus detecting pulpal inflammation in the teeth that are still vital.
- Modified finger probes or tooth adapted instrument to teeth to demonstrate the reliability of the system in the diagnosis of pulp vitality (Figs 1.17 to 1.19).

Disadvantage

Different or multiple wavelengths may be required to improve the sensitivity of the technique.

Transmitted-light Photoplethysmography (Figs 1.20A and B)

The detection of blood flow within the pulp by passing light through the tooth has been reported. Hemoglobin absorbs certain wavelengths of light, while the remaining light passes through the tooth and is detected by a receptor. Photoplethysmography has been compared with LDF in experiments on skin, and found to be of similar value. The technique has not been successfully developed further for dental application apart from one recent investigation.

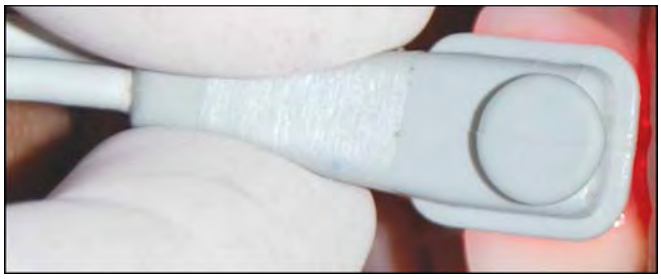


Fig. 1.17: Modified finger probe

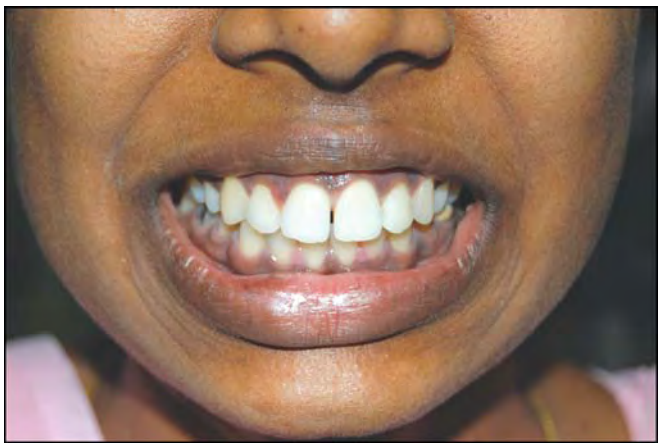


Fig. 1.18: Teeth to be tested for vitality

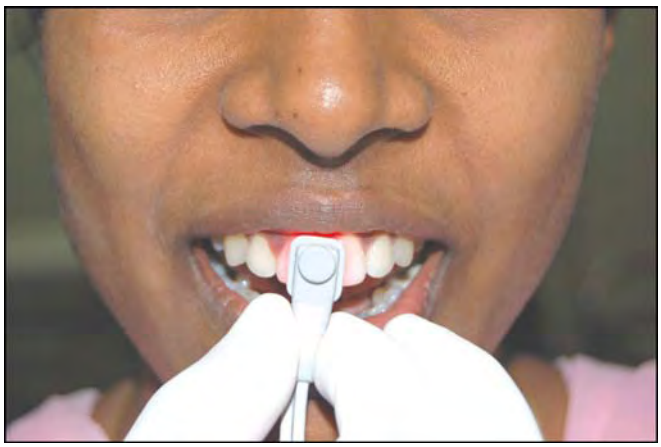
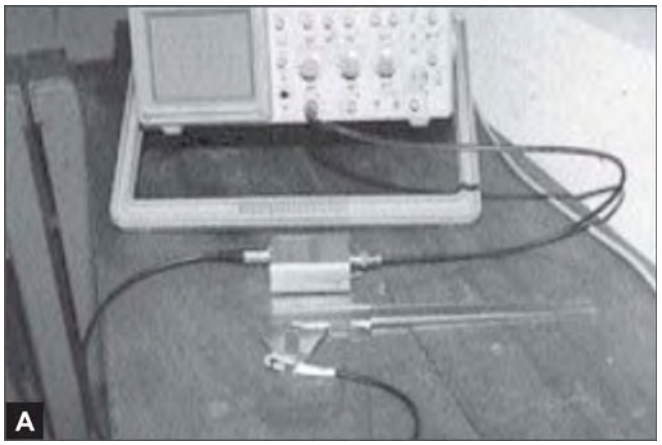
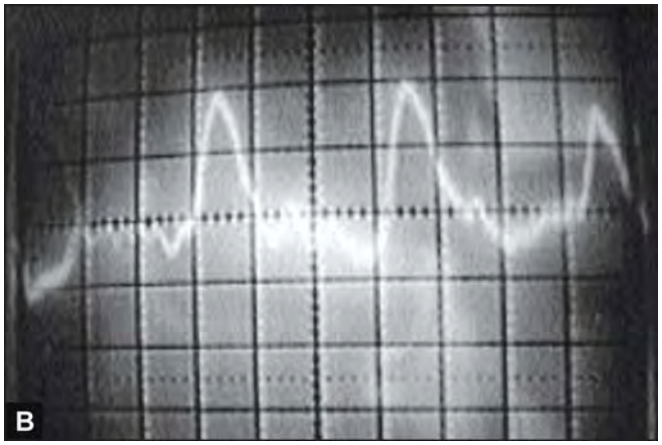


Fig. 1.19: Testing vitality using modified finger probe

Dual Wavelength Spectrophotometry (DWLS) (Fig. 1.21)

- Developed by Chance
- This technique measures oxygenation change of blood





Figs 1.20A and B: Photoplethysmography equipment

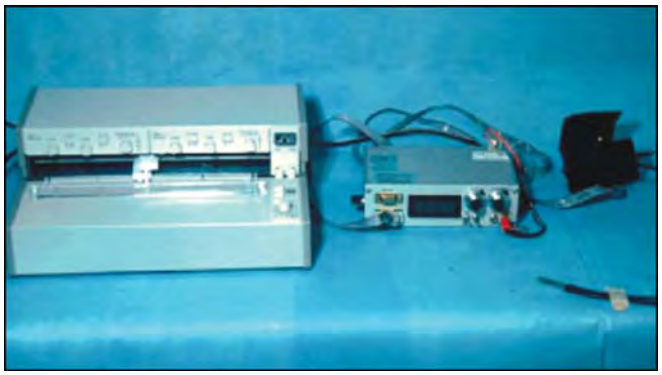


Fig. 1.21: Dual wavelength spectrophotometer

- This identifies the teeth with pulp chamber that are empty, filled with pulp tissue or filled with oxygenated blood.
- Wavelength of 760 nm and 850 nm were used
- The instrument might be useful not only in determining pulp necrosis, but also the inflammatory status of the pulp. The instrument shows promise as a pulp tester as it is non-invasive, objective, small and portable.

Liquid Crystal Testing

Liquid crystals can be used to determine the vitality of dental pulp. This method is based on the principle that if pulp becomes non-vital, the tooth will not have any internal blood supply and thus should exhibit lower surface temperature than that of vital tooth.

Howell et al (1970) carried out a study to determine the pulp vitality of tooth using cholesterol crystal.

There are 3 types of liquid crystal, termed nematic, smectic and cholisteric according to their molecular arrangement, (Ferguson 1964). Crystalline cholesterol crystals when heated to their melting point become cloudy liquid, exhibiting crystal like properties under polarized light. During this stage the cholesterol substance is neither crystal nor liquid but it is in a state known as mesophase. The liquid crystals when heated through their mesophase produces various colors and this color produced when placed on surface of teeth give an indication of its being vital or non-vital.

Method of use: The teeth in question are isolated using rubber dam and a thin black strip coated with cholestric crystals with a mesophase of 30°C-40°C is applied to the teeth and the color change is noted on the calibrated scales using two thermal sensitive devices—thermistor and thermocouple.

Inference of the Color Change

Vital (colors): Blue-green, Green-blue, Red-green, Green

Non-vital (colors): Green, Red, Yellow, Yellow-red

Hughes Probeye Camera (Fig. 1.22)

Hughes probeye camera is capable of detecting temperature changes as small as 0.1°C. It has also been used to measure pulp vitality experimentally. This method is used to measure the blood flow in the pulp.

Hughes probeye camera consists of thermal video system with a silicon close up lens with a resolvable spot size of 0.023 inch. It was possible to focus accurately on individual teeth.

The teeth in question are isolated with rubber dam. The isolated teeth are cooled with a steam of cold air.

Fig. 1.22: Hughes probeye camera

There is symmetrical cooling of teeth of about 22°C. After the cessation of cooling with stream of air, the teeth are rewarmed to their former temperature. The difference is noted with camera. Vital teeth rewarm within 5 seconds whereas non-vital teeth take up to 15 seconds to rewarm. It may be assumed that more rapid warming of vital teeth is due to an intact blood supply.

Disadvantage

- Need for constant ambient temperature

Electronic Thermography (Fig. 1.23)

Thermography is a term given to methods of temperature pattern resolution and analysis. The utility of thermography in diagnosis is based on the fact that the disease processes and abnormal conditions may result in different temperature patterns because of alterations in blood supply or the presence of inflammation. Sensors used to record temperatures may be small electric probes called thermistors (which are used for point determination) or infrared scanners (which are used to record temperature over wide areas). Infrared scanner looks like small television cameras. When an individual is viewed by such a scanner in a draft free, temperature controlled environment, the temperature differences recorded are displayed as a color image on a video monitor. Color differences may represent temperature change as little as 0.1°C. For use in temperature measurement the brightest (warmest) parts of the image are customarily colored white, intermediate temperatures reds and yellows, and the dimmest (coolest) parts blue (Fig. 1.24).

Fig. 1.23: Infrared imaging system

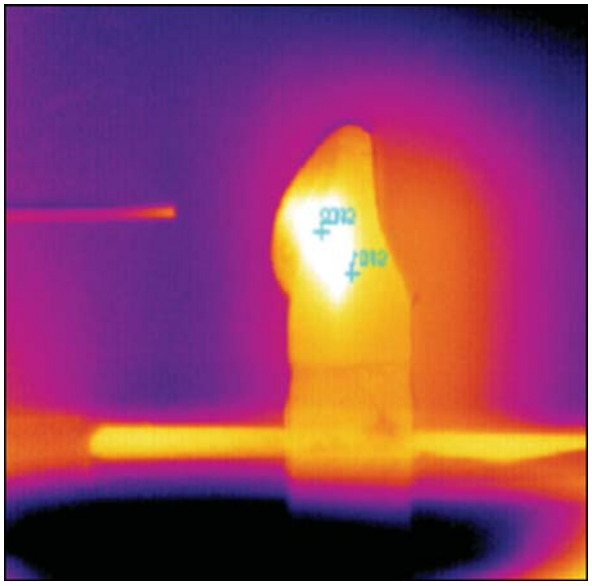


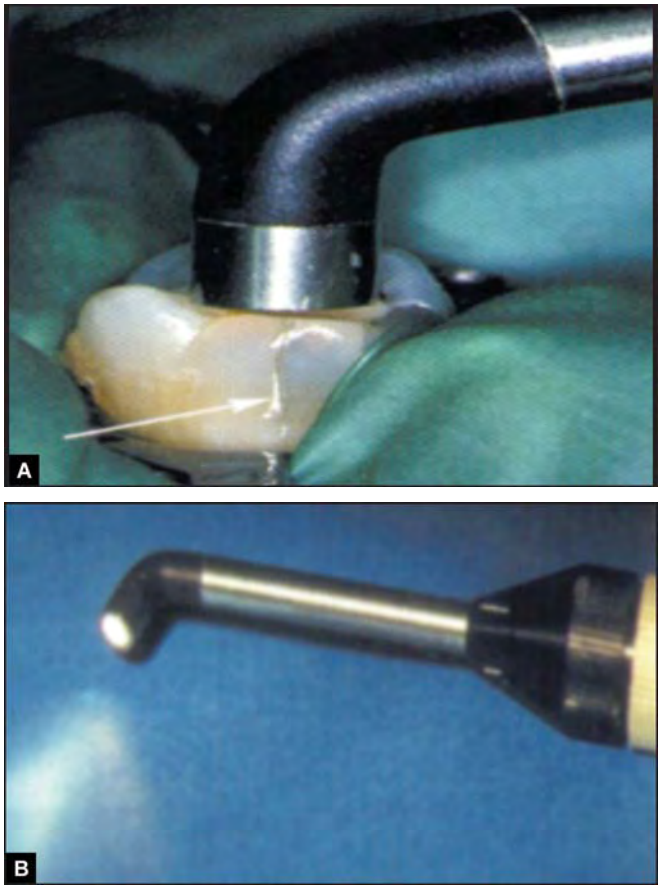
Fig. 1.24: Infrared thermographic image of a central incisor

Transilluminations

Fiberoptic Transillumination (Figs 1.25A and B)

The use of fiberoptic lighting and chair side magnification has become indispensable in search for cracks, fractures, undetected canals and obstructions in the root canal therapy.

Method of use: Holding a fiberoptic illuminating device horizontally at the gingival sulcus in a dimly lit



Figs 1.25A and B: Fiberoptic transillumination

operatory may reveal a vertical fracture line or it may make a suspected line more visible.

Normally the crown of an intact tooth will be illuminated uniformly by the fiberoptic light. If a fracture exists, the light will illuminate the side of the crown that it contacts. However, the portion of the crown on the opposite side of the fracture will remain dark.

A specialized fiberoptic wand, a fibreoptic attachment, a bore light, or a fiberoptic handpiece may be used for this purpose. Composite curing lights are not recommended for this purpose as they are very bright and despite the fracture, may illuminate the entire crown.

If the tooth contains a restoration, it may be necessary to remove it to expose the fracture line. By this method, a pulpless tooth that is not noticeably discolored may show a gross difference in translucency when the shadow produced on a mirror is compared to that of adjacent teeth.

If the involved tooth with vertical fracture or crack is not readily identified, it may be necessary to thoroughly examine all of the teeth in the half arch or opposing arch; depending on how specifically the patient can localize the area of pain. For the record and for the possibility of additional later treatment, the condition of all teeth in the immediate vicinity should be recorded.

Limitations: Although fiberoptic transillumination will not reveal discoloration caused by extravasations of blood after trauma or calcification of pulp chamber, this discoloration is not reliably related to the health of the pulp. Therefore, it should not be used to determine pulp vitality.

Orascopy or Endoscopy (Fig. 1.26)

Orascopy or endoscopy is a new method for enhanced visualization in endodontics using a flexible, fiberoptic endoscope. The fiberoptic probes are available in two diameters 0.7 and 1.8 mm. The probes provide a large depth of field and there is no need to refocus after the initial focus.

Mechanism of Action

Once the probe is applied, the operator views the operating area from the magnified image displayed on the monitor. The 0.7 mm probe can be inserted into the root canal for internal viewing. This scope sends images to a solid state video camera, a medical-grade

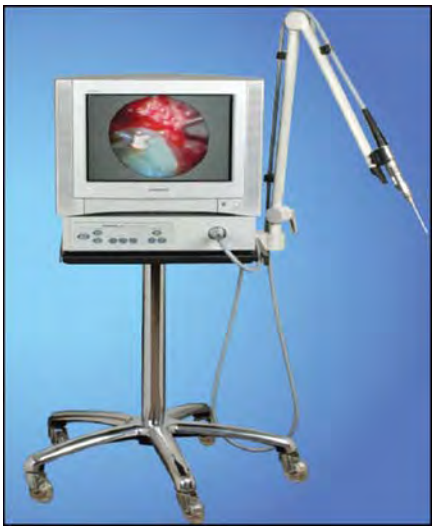


Fig. 1.26: Orascope

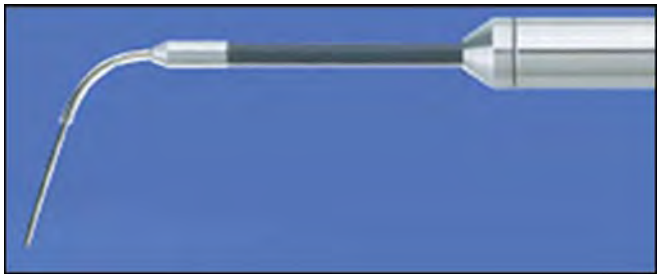


Fig. 1.27: Probe

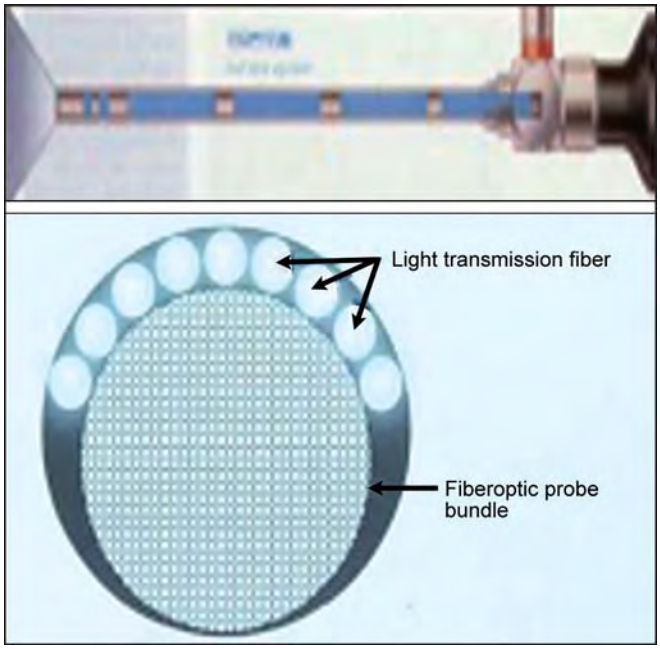


Fig. 1.28: Cross-sectional area of probe

video monitor, and digital-image capture device. Other documentation options are digital video recording system and a standard 35 mm photo camera that can be attached to the proximal end of the scope for very high resolution images.

Each probe consists of a flexible fiberoptic bundle with fibers that emit light generated by the metal halide light source and others that transmit the image (Figs 1.27 and 1.28). The digital signal processing unit filters the image to produce an enhanced, consistent image. Storage and retrieval of images can be accomplished with connection to the clinical chair-side work station. Infection control is provided by placing disposable, optical-grade, plastic sheaths over the distal end of the probe.

Advantages:

1. Endoscopic endodontics allows the clinician to have a nonfixed field of vision.
2. The probes can be manipulated at various angles and distances from an object without loss of focus or image clarity.
3. With the orascopy, fine fracture lines, accessory canals, apical tissues are also viewed.

Radiographic Techniques

Importance of Radiography in Endodontics

A single radiograph is a two dimensional shadow of a three dimensional object. For maximum information, the third dimension must be visualized and interpreted. Radiographs perform essential functions in three areas. The three areas of applications are:

1. Diagnosis
2. Treatment
3. Recall

1. Diagnosis
   - Identifying pathosis
   - Determining root and pulpal anatomy
   - Characterizing normal structures.
2. Treatment
   - Determining working lengths
   - Moving superimposed structures
   - Locating canals
   - Differentiating canals and periodontal ligament space.
   - Evaluating obturation
3. Recall
   - Identifying new pathosis
   - Evaluating healing

Limitations: Radiograph is a two dimensional shadow of a three dimensional object. Radiographs are unable to detect the bone destruction or pathosis when it is limited to the cancellous bone. Some have proven that radiolucencies usually do not appear unless there is external or internal erosion of cortical plate. This factor must be considered in evaluating teeth that become symptomatic but show no radiographic changes. Proper dark room organization, film handling and adherence to the time and temperature method of film processing play important roles in producing films of high quality.

Xeroradiography (Marco 1984)

Xeroradiography is a diagnostic system which allows images to be recorded using the xerographic copying process. This technique has ability to produce images of both soft and hard tissues and gained popularity in the 1960s with the applications to mammography. It was applied by the orthodontists to lateral cephalometry. Much experimental work was carried out in the 1970s on using the technique for intraoral radiography, concluding that xeroradiographic images were diagnostically superior to conventional film in detecting tooth, bone and soft tissue changes, principally because of the greater exposure latitude and unique property of edge enhancement. The technique has been applied to periodontics and to the detection of small caries lesions.

Equipment: In xeroradiography, the silver halide emulsion used in conventional radiograph is replaced by electrostatically charged aluminium plate backing which carries a thin plate of selenium, to which a uniform positive charge is applied. The X-ray photons reaching the plate caused selective discharge on the selenium surface producing a latent image charge pattern. In the special processor a visual image is produced by spraying the plate with a white toner, which is attracted to the remaining charged areas. The powder is then picked up and transferred to a special paper medium. This forms the final black and white hard-copy image that resembles a conventional radiograph.

Technique: The charged plate is held in a light tight cassette in a plastic bag and is exposed intraorally in the routine manner by a conventional dental X-ray machine. The X-rays dissipate the charge on the photo receptor plate in a pattern that corresponds to the absorption of the X-rays by the object being radiographed. A latent electrostatic image is then formed.

The exposed plate is then placed in the processing machine and latent image is transformed into a real image on opaque paper that can be viewed by reflected light or illuminations. The copying process presently takes 20 seconds. The photoreceptor plate is then sterilized, reconditioned and recharged and is reusable.

Advantages

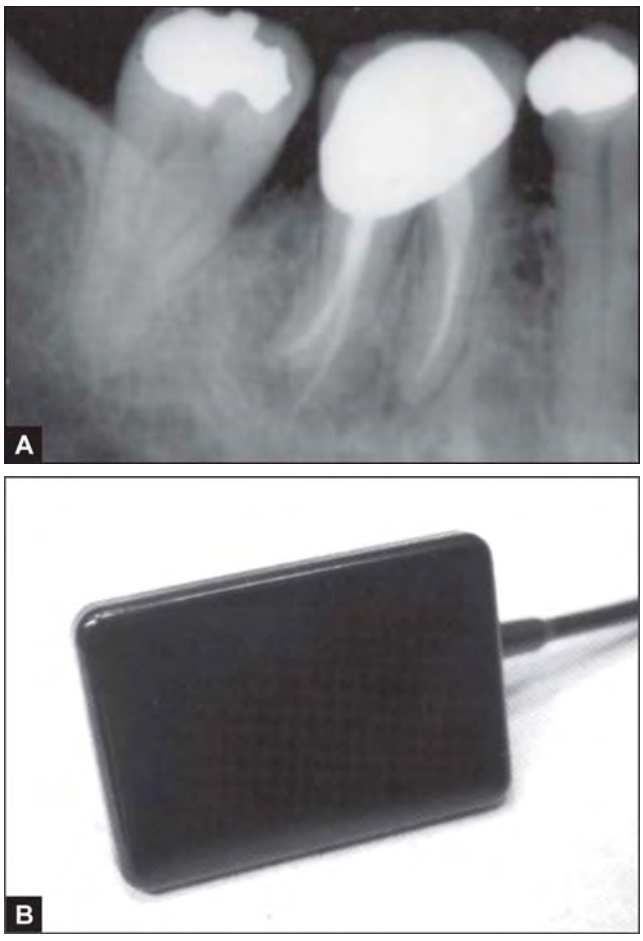
- Gives excellent diagnostic information.
- It can be best utilized by specialists.

Disadvantages

- Small intraoral plate is hard and uncomfortable in the mouth
- Developing process is somewhat temperamental.

Digital Radiography (Figs 1.29A and B)

Since the discovery of X-rays in 1895, film has been the primary medium for capturing, displaying, and storing radiographic images. It is a technology that dental practitioners are the most familiar and comfortable with in terms of technique and interpretation. Digital radiography is the latest advancement in dental imaging and is slowly being adopted by the dental profession. Digital imaging incorporates computer technology in the capture,



Figs 1.29A and B: Radio visiography (Dr Frances Mouyens)

display, enhancement, and storage of direct radiographic images. Digital imaging offers some distinct advantages over film, but like any emerging technology, it presents new and different challenges for the practitioner to overcome.

Fundamentals of Digital Radiography

The term digital radiography refers to a method of capturing radiographic images using a sensor, breaking it into electronic pieces and presenting and storing the image using the computer. In digital radiography, the patient is exposed to X-radiation similar to conventional radiography and a detector, or sensor is placed inside the patient's mouth to receive the image information of the exposed area. A computer stores the image and displays it within moments of exposure.

Radiation Exposure

Digital radiography requires less X-radiation than conventional radiography because the sensor is more sensitive than conventional films. Exposure times are 50 to 80 percent less than that required for conventional radiography using E speed films. For example exposure time required to produce an image for digital radiography is three impulses (3/60 sec or 0.05 sec) which is far less than (12/60 sec or 0.2 sec) required for E speed film.

Equipment

i. X-ray machine
ii. Intraoral sensors
iii. Computer

Types of Intraoral Sensors

a. Charge coupled device [CCD]
b. Complementary metal oxide semiconductor/active pixel sensor [CMOS/APS]
c. Charge injection device [CID]

Types of Digital Imaging

Charge coupled device [CCD]: It is the most common image receptor used in dental digital radiography. The CCD technology used in digital radiography relies on a specialized fabrication process that is expensive to manufacture.

The electrons that make up the silicon CCD can be visualized as being divided into an arrangement of blocks or picture elements known as pixels. When X-rays activate electrons and produce a collection of these tiny image units, an electronic latent image is produced, which is transmitted and stored in a computer and can be converted to visual image on screen or printed on a paper.

Complementary metal oxide semiconductor/active pixel sensor [CMOS/APS]: This is another technology used in digital radiography. Although CMOS process is standard in the making of semiconductor chips, it was not until APS was developed that CMOS became useful as a sensor in dental digital radiography. Manufacturers claim 25 percent greater resolution and an additional advantage of low cost and greater durability than CCD.

Charge injection device (CID): CID is a silicone-based solid state imaging receptor much like CCD. This technology was used for intraoral video camera platform. No computer is used to process the images and printouts can be directly taken from the printer dock.

Computer: The computer digitalizes, processes, and stores the information received from the sensor. The monitor allows the immediate viewing, images can be magnified, contrast analyzed and even linear and angular measurements can be obtained.

Three methods of digital imaging currently exist:

i. Direct digital imaging
ii. Indirect digital imaging
iii. Storage phosphor imaging

Direct digital imaging: Essential components include an X-ray machine, an intraoral sensor and a computer system. Sensor is placed in the patient's mouth and exposed to radiation. The sensor captures the radiographic image and then transmits to a computer monitor. Within seconds of exposing the sensor to X-rays, image appears on the computer screen. Software is used to store and enhance the image.

RVG digitizes ionizing radiation and provides an instantaneous image on a monitor thereby reducing radiation exposure by 80 percent. RVG equipment has a fiberoptic intraoral sensor (with a selemium coated plate).

Fig. 1.30: Components of RVG

Fig. 1.31: The video monitor and display processing unit

The RVG has three components (Fig. 1.30)

- The "radio" component (X-ray unit).
- The "visio" portion.
- The "graphy" component.

a. The RADIO component consists of a hypersensitive intraoral sensor and a conventional X-ray unit.
b. The VISIO portion consists of a video monitor and display processing unit (Fig. 1.31).
c. The GRAPHY component is a high resolution video printer that instantly provides a hard copy of the screen image using the same video signal.

The RVG system appears to be promising for the future of endodontics. But, the resolution of RVG is slightly lower than that produced with conventional terms, which can, however, be improved through enhancement

Indirect digital imaging: The components include a CCD camera and a computer. In this method an existing X-ray film is "digitalized" using a CCD camera which scans and digitalizes the image. But this method is found to be inferior to direct digital imaging as the resultant image is only a copy of the original.

Storage phosphor imaging: A wireless digital imaging system, a reusable plate coated with phosphorus is used instead of a sensor with a fiber-optic cable. The phosphor-coated plates are flexible and can intraorally fit like a radiographic film. Storage phosphor imaging records the diagnostic data on plates following exposure to X-ray source and then uses a high speed scanner to convert the information to electronic files. Processing uses laser scans because of which it is less rapid compared to direct digital radiography.

Advantages

1. *Increased speed of image viewing:* Near instantaneous image allows multiple angles to be taken to help in location of the canals, identification of canal curvatures, verification of working lengths, and immediate postobturaton results.
2. *Reduced exposure to radiation:* Radiation exposure is 50 to 80 percent less than conventional radiography.
3. *Lower equipment and film cost:* Eliminate the need for purchasing films, processing equipment and dark room is not necessary.
4. *Superior gray scale resolution:* Digital radiography uses 256 colors of gray compared to 15 to 20 shades of gray differentiated on a conventional film.
5. *Increased efficiency:* Dental personnel can be more productive as it does not interfere with the patient's care. Helps in communication, storage as well as record maintenance.
6. *Enhancement of diagnostic image:* Features such as colorization and zoom allow users to highlight a condition. With the digital subtraction, gray scale can be reversed and enhancing can be done.
7. *Effective patient education tool:* Patients can view radiographic images on a monitor that facilitates dialogue and rapport with the clinician.

Disadvantages

1. Initial setup costs
2. *Image quality:* Continues to be a source of debate, conventional X-ray has the resolution of 12 to 20 lp/mm. Digital imaging using a CCD has a resolution closer to 10 lp/mm. Given that human eye can only resolve 8 to 10 lp/mm, a CCD is adequate for the diagnosis of a dental disease.
3. *Sensor size:* Thicker than the intraoral film. May be uncomfortable and elicits gag reflex.
4. *Infection control:* Sensors cannot be heated or cold sterilized and require complete coverage with disposable plastic sleeves.
5. *Legal issues:* As the original digital image can be manipulated, it is questionable whether these can be used as evidences in lawsuits.

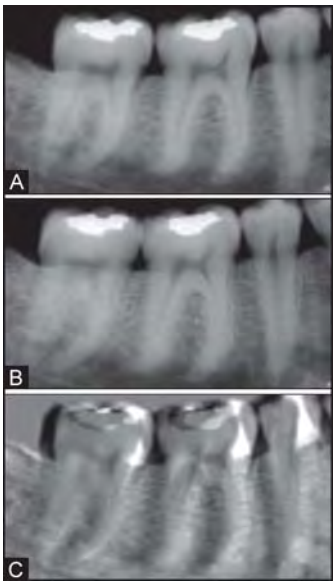
Manipulation of Images

1. *Magnification:* Using a 15" monitor, The Digora and Schick images are displayed in 5" x 7" frames. These images can be usefully magnified 2-3 times.
2. *Variable contrast:* All systems will allow for unlimited gray scale adjustments.
3. *Variable density:* All systems will allow unlimited adjustments from black to white. No more retakes due to over or under exposure.
4. *Labeling important information:* No more orphan films. Each image is labeled by name and date.
5. *Highlighting and colorization:* This feature is snazzy but really is most useful when impressing kids.
6. *Printing options:* Dye sublimation-Photographic quality "permanent" color prints on card stock can be produced in about 5 minutes. It is a bit expensive. Thermographic black and white prints can be produced in about 1 minute. These are unstable and are not readable after a couple of years.

Digital radiography is commonly used in endodontic diagnosis and treatment. It will give immediate images helping in faster diagnosis and biomechanical preparation.

Digital Subtraction Radiography (Figs 1.32A to C)

At some time after the treatment, another image is generated. The two images are digitized and compared on a pixel-by-pixel basis. The resultant image shows only the changes that have occurred and "subtracts" those components of the image that are unchanged. This is an image enhancement method,



Figs 1.32A to C: **(A & B)** Pre- and post-treatment radiographs **(C)** Subtraction image

resulting in the area under focus being clearly displayed against a neutral gray black background or it is superimposed on the radiograph itself, i.e. required areas are enlarged against the entire background. The digital subtraction radiography may be used to assess the carious lesion and also periapical lesions improved through enhancement procedures.

Ultrasound Real-time Imaging (Echography)

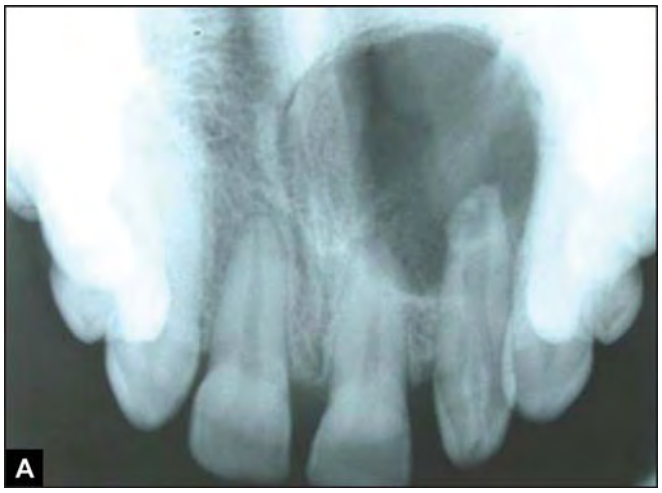
CT scan	*Ultrasonography*
Noninvasive	Noninvasive
Excellent tissue differentiation	Provides real-time imaging
Exposure to ionizing radiation	Uses no ionizing radiation
Expensive	Inexpensive

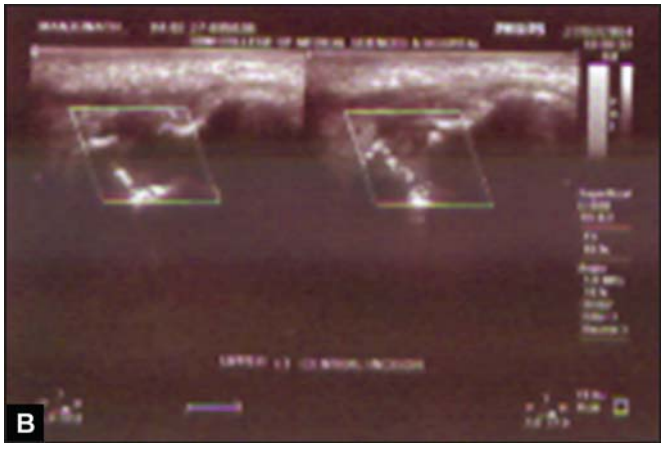
Principle: Real-time ultrasound imaging, also called Echotomography or Echography, has been a widely used diagnostic technique in many fields of medicine. The imaging system in echographic examination is based on the reflection of ultrasound waves called 'echoes'. The ultrasound oscillating at the same frequency is generated, as a result of the piezoelectric effect, by a synthetic crystal and is directed towards the area of interest via an ultrasonic probe. The different biological tissues of the body possess different mechanical and acoustic properties. When the ultrasound wave encounters the interface between two tissues with different acoustic properties, they undergo the phenomena of reflection and refraction.

The echo is the part of the ultrasound that is reflected back to the crystal. The intensity of the echoes depends on the difference in acoustic properties between two adjacent tissue compartments: the greater the difference, the greater the amount of reflected ultrasound energy, and the higher the echo intensity. Echoes are then transformed into electrical energy and into light signals in a computer inside the machine. The movement of the ultrasonic probe produces the ultrasound images seen on the monitor over the part of interest in the body. Since each movement gives one image of the tissue and there is an average of 30 images per second, the exam will appear in the monitor as moving images.

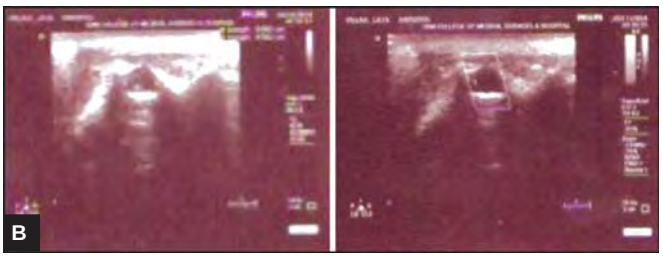
The color power Doppler is based on the red blood cell's Rayleigh's scattering effect and on the Doppler effect. When applied to the echographic examination, it allows representing the presence and direction of the blood flow (Doppler), under the format of color spots superimposed to the images of blood vessels (color), and the intensity of the Doppler signal with its modifications in real time.

The intravenous injections of substances (contrast mediums) will increase the echogenicity of the blood.





Figs 1.33A and B: Comparison of ultrasonography and radiographic findings of radicular cyst

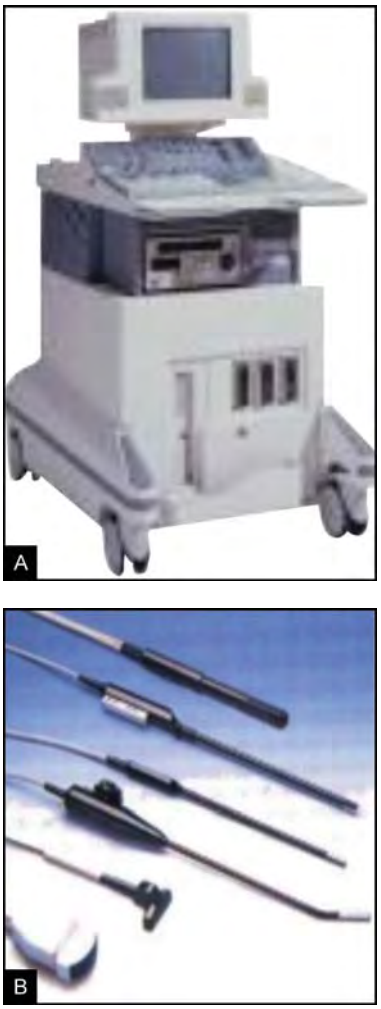


Figs 1.34A and B: Comparison of ultrasonography and radiographic findings of periapical granuloma

Ultrasound Imaging in Endodontics (Figs 1.33 and 1.34)

The application of echographic examination to the study of endodontic disease has been attempted with success. The technique is easy to perform and may show the presence, exact size, shape, content and vascular supply of endodontic lesions in the bone.

The echographic probe, covered with a latex protection and topped with the echographic gel, should be moved in the buccal area of the mandible or the maxilla, corresponding to the root of the tooth of interest. The regular probe, so far, has been performing well even if a more specific instrument for dental use should be made available (Figs 1.35A and B).



Figs 1.35A and B: Ultrasound equipment

Interpretation: Alveolar bone appears as white if healthy; the contours of the roots of the teeth are even whiter, this tissue is then considered hyperechoic.

A fluid-filled cavity in the bone appears as a hypo-reflecting surface (dark) to different degrees, depending of the cleanliness of the fluid:

A simple serous filled cavity has no reflection (anechoic or transonic).

Solid lesions in the bone have a "mixed echogenic appearance", which means their echoes are reflected with various intensities.

If the bone is irregular or resorbed in proximity of the lesion, this can be seen as an inhomogeneous echo; if the bony contour limiting a lesion is reinforced, then it is very bright.

Major anatomic landmarks, such as the mandibular canal, mental canal, and maxillary sinus, are clearly distinguished and mostly transonic. At the color power Doppler, the vascularization within the lesion and around it can be seen; the details of it are enhanced by the use of contrast mediums.

A differential diagnosis between cystic lesions and granulomas may be done based on the following principles:

Cystic lesion: A transonic, well defined cavity filled with fluids and with no evidence of internal vascularization at the color power Doppler.

Granuloma: A distinct lesion showing not well-defined contours, which can be frankly corpusculated (echogenic), or may show both corpusculated and hypoechoic areas exhibiting a vascular supply at the color power Doppler with or without contrast medium.

The sensitivity of the technique makes possible a distinction between serous and inflammatory exudates in cysts. However, at its current stage of development, the echographic examination may not help in distinguishing between other kind of cystic conditions (i.e. keratocysts, traumatic bone cyst, developmental cyst) as the cavity is well visualized and its contents, be it fluid or particulate, can hardly be distinguished. Fibrous tissue within a lesion maybe distinguished with more details; also calcified particles can be observed.

Computerized Tomography (Fig. 1.36)

CT is a radiographic technique that blends the concept of thin laser radiography with the computer image.

Techibana has reported about the use of CT in endodontics. It is possible to determine the buccolingual and mesiodistal widths of teeth and visualization and extension of major anatomic structures and assessment of exact dimension of endodontic lesions around the tooth to be treated (Fig. 1.37).

Chronic apical periodontitis can also be seen with the CT scan. When a lesion is at an early stage, or when the slice covers the smallest portion of a well-established one, it is seen as an enlargement of the periodontal space, this can also be clearly seen as a small osteolytic reaction around the root's tip.

Vertical root fractures or split teeth may be easily detected in CT scans.

Trope et al pioneered the application of CT to endodontic imaging. He concluded that cystic cavities

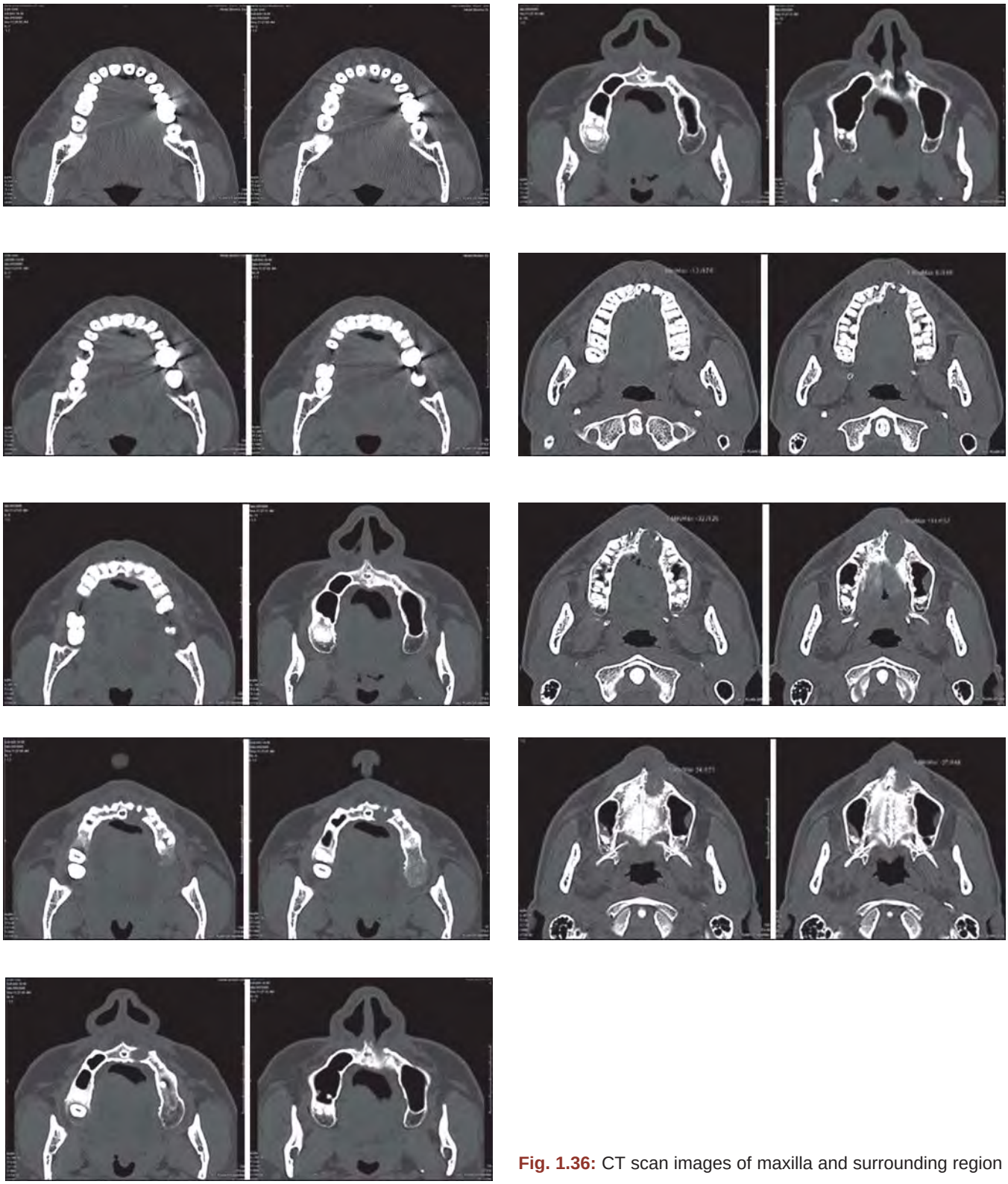


Fig. 1.36: CT scan images of maxilla and surrounding region

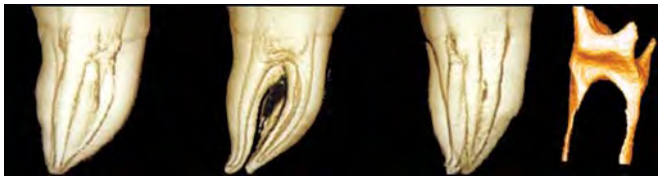


Fig. 1.37: Estimation of pulpal dimensions using CT

could be differentiated from granulomas based on their appearance in the tomographs. They observed that a cyst would appear as area of darkness when compared to a granuloma or to the fibrous tissue of an apical scar. Spiral CT scans are said to be more accurate in the orofacial diagnosis.

Ortho CT has been described as a compact CT apparatus in which cone beam geometry is used to image the maxillofacial area with high resolution. Data are collected using a dental panoramic machine. In this system, the entrance radiation dose is lower than that of conventional CT. Because of its reduced field size, it is not possible to examine lesions exceeding 30 mm without repeated scanning. Another drawback is the inability of this technique to discriminate soft tissues because of its low contrast resolution.

Tomosynthesis is an analogue of CT that uses a number of conventional radiographic images on films to extract a slice through the region of interest, by overlapping the images and eliminating the unwanted parts of the object.

TACT (Tuned Aperture Computed Tomography) (Fig. 1.38)

It is a more specific digital version of tomosynthesis. It uses a fiducial mark for the registration of the images and requires a conventional radiographic apparatus, a digitizing system and specific software. It has been shown to visualize root canals better than conventional radiographs, and is suitable for evaluation of crestal defects in the jaws.

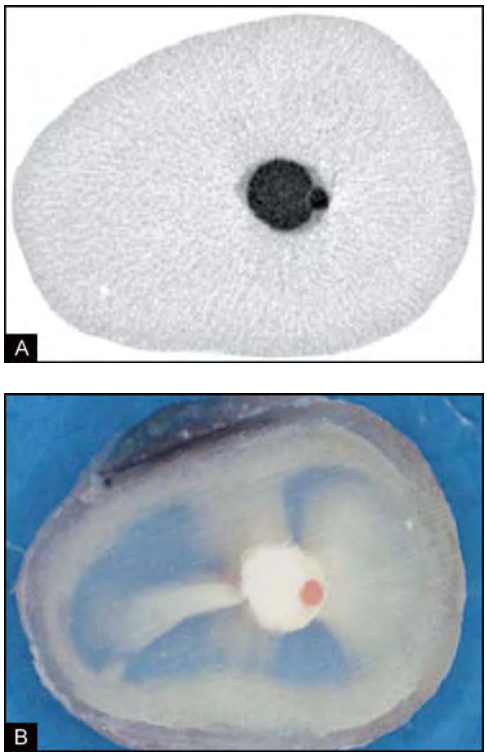
The TACT system uses digital radiographic images and the TACT software correlates the individual images of a subject into a layering of images that can be viewed into slices. The TACT image is composed of a series of 8 digital radiographs that are assimilated into a reconstructed TACT image. Preliminary studies have shown that TACT has advantages over conventional film in the visualization of canals in the human molar.

Fig. 1.38: TACT equipment

Fig. 1.39: Micro-CT equipment

MICRO-CT uses stacked fan-beam geometry and produces 3D reconstruction of the objects examined (Fig. 1.39). Such a desktop micro-CT has been used to reconstruct root canals without requiring a previous disassembly of the teeth. In recent evaluations on induced periapical lesions in mice, micro-CT, performed with 150 micro tomographic slices of 17 mm increments, gave 3-D morphometrical data on the study of periapical lesions that compared well with the histology. Few authors found that the widest area of the destructive pattern of induced periapical lesions appeared right under the apical foramen, and that the resorptive lesions were not uniform in nature.

They also noticed that the 2-D measurement of area of the periradicular lesions and the 3-D measurement



Figs 1.40A and B: (A) Micro-CT cross-section of root (B) Histologic section at the same level

of their volume were highly correlated. Currently, the use of micro-CT may be limited to in vitro measurements of small samples due to the high radiation dose required. Experimental systems with reduced dose are being tested (Figs 1.40A and B).

Advantages:

- Provides images for 3D reconstruction of roots, root canals and teeth
- Preservation of structure which are difficult to visualize with conventional X-ray.

Disadvantages:

- Expensive
- Skin dose is large
- Time consuming

Magnetic Resonance Imaging (MRI) (Fig. 1.41)

Nuclear magnetic resonance, also called MRI, has been available as an imaging technique since 1984.

Principle: MRI combines the use of a magnetic field and radiofrequency antenna. During the MRI exam a magnetic field is created: this causes the protons in

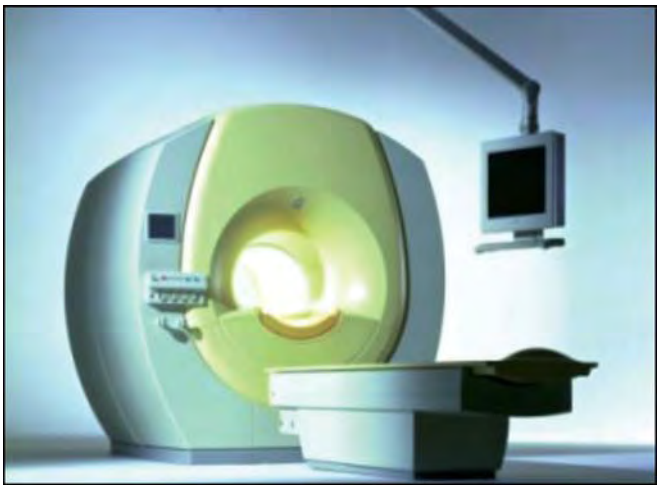


Fig. 1.41: MRI equipment

the atoms of water, within the tissues to be examined, to line up. Then pulses of radiowaves are sent from a scanner which move many of the protons out of alignment. As the nuclei realign back into proper position, they send out the radio signals (resonance) that are captured by a radio antenna. Different atoms in the body absorb radiowaves at different frequencies under the influence of the magnetic field.

The signals are received and measured from a computer system that analyses and converts them into an image of the part of the body being explored.

Magnetic resonance is a completely non-invasive technique. Its best performance is in showing soft tissues and vessels whereas it does not provide great details of the bony structures.

Disadvantages

- Longer scanning time compared to CT.
- Cannot be used in patients carrying a pacemaker or metal pieces in the areas to be investigated.
- It is an expensive examination and in most of the systems the patient must be placed in a narrow tube.

Application and Interpretation of MRI in Endodontics

Application of MRI to the dental field started in the late nineties. Studies have been reported on the temporomandibular joints, on the assessment of the jaw bones prior to implant surgery, and on the differential diagnosis of ameloblastoma and odontogenic keratocysts.

Gahleitner and his group were the first to apply MRI to the study of the jaws and teeth. They showed that MRI gives good imaging of the jaw bones, including teeth, pulp spaces and periapical tissues. Pulps were better visualized after administration of a contrast medium.

In MRI enamel and dentine appear black, the pulp chamber and canal either white or light gray, root fillings are dark. The cortical bone is a black area outlined by lighter, soft external tissues and internal fatty marrow.

On STIR (fat annulled scans), fatty marrow has a low signal and appears dark gray. Periapical lesions are clearly seen in the images both on coronal and transverse sections. Any interruption of the cortical plates is also easily seen. Areas of bone sclerosis, which usually surround the periapical lesion, are seen as very low signals (black). On fast low angle shots T1, they are seen as moderate a signal (gray) as opposed to the fatty medullary marrow, which gives a strong white signal.

Studies have shown that MRI can be used for investigation of pulp and periapical conditions, the extent of the pathosis and the anatomic implications in cases of surgical decision-making. When an infective lesion like a periapical abscess is expanding fast in the jawbones and in corresponding soft tissues, degenerating into osteomyelitis, MRI becomes an elective diagnostic technique.

Computerized Expert System

The COMENDEX (CES) is a database management software system which was used for the diagnosis of selected pulpal pathosis Appropriate diagnostic case facts are obtained and this data is entered into the computer. The computer checks and gives out the diagnosis. With rapid advances being made in the field of computers, we may get many more programs for efficient endodontic diagnosis.

Xenon-133 with Radiolabeled Microspheres

- Introduced by Ronni
- Was used to check status of blood circulation

The material is a radioactive substance and pulpal blood circulation is checked by washout of Xenon-133 radioisotope using radiolabelled microsphere injection method. However, the use of radioactive materials is expensive, restricted on humans, and requires special licencing requirements.

Miscellaneous

Detection of interleukin-1 beta in human periapical lesion: The inflammatory periapical lesions are the common sequelae of the infected pulp tissue. Numerous cell types including PMN leucocytes T and B lymphocytes, macrophages and plasma cells are found.

These inflammatory cells produce interlukin-1; it acts as a mediator for various inflammatory and immunologic responses. This lymphocytes activating factor IL-1 is responsible for osteoclast activation which results in bone resorption which is a feature of inflammatory response.To this point, the most promising of these experimental methods are those using the measurement of light passing through or deflected from the blood in the pulp.

SUGGESTED READING

1. Bhaskar SN, Rappaport HM. Dental vitality tests and pulp status. J Am Dent Assoc 1973;86: 409-11.
2. C Grace Petrikowski, Introducing Digital Radiography in the Dental Office: An OverviewJCDA o www.cda-adc.ca/jcda o October 2005;71(9):651-51f.
3. David A. Spratt Significance of bacterial identification by molecular biology methods Endodontic Topics 2004;9: 5-14.
4. E Cotti, G Campisi V Garau G. Puddu A new technique for the study of periapical bone lesions: ultrasound real time imaging International Endodontic Journal, 2002;148-52.
5. Eli I. Dental anxiety: A cause for possible misdiagnosis of tooth vitality. Int Endod J 1993;26:251-53.
6. Elisabetta cotti and Girolamo campisi Advanced radiographic techniques for the detection of lesions in bone. Endodontic topics 2004;7:52-72.
7. Fanibunda KB. The Feasibility of temperature measurement as a diagnostic procedure in human teeth. J Dent 1986;14:126-9.
8. Grossman LI. Clinical diagnostic methods. In: Endodontic Practice, 11th edn. Philadelphia: Lea and Febiger 1981; 17-22.
9. Howell RM, Duell RC, Mullaney TP. The determination of pulp vitality by thermographic means using cholesteric liquid crystals. A preliminary study. Oral Surg Oral Med Oral Pathol 1970;29:763-68.
10. Isabelle portenier, Tuomos MT. Waltimo and Markus haapasalo Enterococcus faecalis—the root canal survivor and 'star' in post-treatmentdisease. Endodontic Topics 2003;6:135-59.
11. JF Siqueira Jr, IN. Roˆcas, Exploiting Molecular Methods to Explore Endodontic Infections: Part 1-Current

Molecular Technologies for Microbiological Diagnosis J. Endod 2005;31:411-23.
12. JS Rhodes, TR Pittford, JA Lynch, PJ Liepens, RV. Curtis Microcomputerized tomography: a new tool in experimental endodontology. Int Endod J 1999;32:165-70.
13. Kahan RS, Gulabivala K, Snook M, Setchell DJ. Evaluation of a pulse oximeter and customized probe for pulp vitality testing. J Endod 1996;22:105-09.
14. Kells BE, Kennedy JG, Biagioni PA, Lamey PJ. Computerized infrared thermographic imaging and pulpal blood flow: part 2. Rewarming of healthy human teeth following a controlled cold stimulus. Int Endod J 2000;33:448-62.
15. Mesaros SV, Trope M. Revascularization of traumatized teeth assessed by laser Doppler flowmetry: case report. Endod Dent Traumatol 1997;13:24-30.
16. Miwa Z, Ikawa M, Iijima H, Saito M, Takagi Y. Pulpal blood flow in vital and nonvital young permanent teeth measured by transmitted-light photoplethysmography: a pilot study. Pediatr Dent 2002;24:594-98.
17. Odor TM, Pitt Ford TR, McDonald F. Effect of wavelength and bandwidth on the clinical reliability of laser Doppler recordings. Endod Dent Traumatol 1996;12:9-15.
18. Peters DD, Baumgartner JC, Lorton L. Adult pulpal diagnosis. 1. Evaluation of the positive and negative responses to cold and electrical pulp tests. J Endod 1994;20: 506-11.
19. P Carrotte. Endodontics: part 2 diagnosis and treatment planning British dental journal. 2004;197:231-38.
20. Roeykens H, Van Maele G, Martens L, De Moor R. A two-probe laser Doppler flowmetry assessment as an exclusive diagnostic device in a long-term follow-up of traumatised teeth: a case report. Dent Traumatol 2002;18: 86-91.
21. Steven A Held, Yi H. Kao, Donald W. Wells Endoscope-an endodontic application. J. Endod 1996;22:327-29.
22. SR Matteson, ST Deahl, ME Alder PV. Nummikoski advanced imaging methodsCrit rev oral biol med 1996;7(4):346-95.
23. Thomas Von Arx, Stephen hunenbart, Daniel Buser Endoscope-and - video assisted endodontic surgery, Qintessence international Indian edition 2002:2: 61-65.
24. Y Kimura, P Wilder-Smithand K. Matsumoto Lasers in endodontics: a review International Endodontic Journal, 2000;173-85.

2 Pulpal and Periradicular Diseases

The pulp has been described both as a highly resistant organ and as an organ with little resistance or recuperating ability. Its resistance depends on cellular activity, nutritional supply, age, and other metabolic and physiologic parameters (Fig. 2.1).

This variability has led to the remark that: "Some pulps will die if you look crossly at them, while others can't be killed with an ax."

CAUSES OF PULP DISEASE

The causes of pulp disease are:

I. Physical
II. Chemical
III. Bacterial

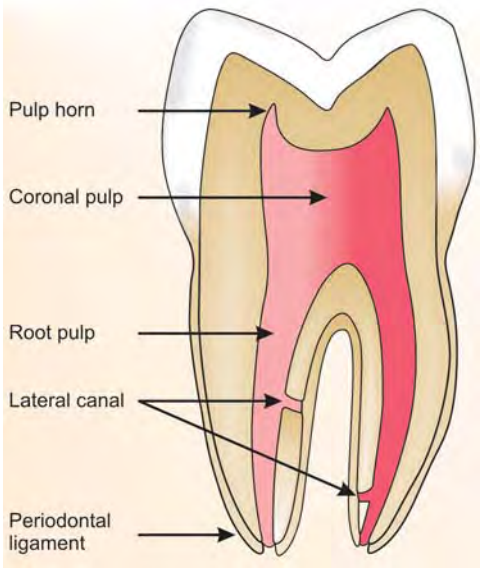


Fig. 2.1: Anatomy of the pulp

I. *Physical*
   A. Mechanical
      1. Trauma
         a. Accidental (contact sports)
         b. Iatrogenic dental procedures (wedging of teeth, cavity or crown preparation.
      2. Pathologic wear (Attrition, abrasion, etc.)
      3. Crack through body tooth (cracked tooth syndrome)
      4. Barometric changes (Barodontalgia).
   B. Thermal
      1. Heat from cavity preparation, at either low or high speed
      2. Exothermic heat from the setting of cement
      3. Conduction of heat and cold through deep fillings without a protective base
      4. Frictional heat caused by polishing a restoration.
   C. Electrical (Galvanic current from dissimilar metallic fillings).

II. *Chemical*
   A. Phosphoric acid, acrylic monomer, etc.
   B. Erosion (Acids).

III. *Bacterial*
- Toxins associated with caries
- Direct invasion of pulp from caries or trauma
- Microbial colonization in the pulp by blood borne microorganisms (anachoresis).

Physical Causes

Physical causes include:
- Mechanical

- Thermal
- Electrical injuries.

Trauma

- Traumatic injury may or may not be accompanied by fracture of the crown or root (Figs 2.2 and 2.3).
- More in children than in adults.
- May be due to a violent blow to the tooth during a fight, sports, automobile accident.
- Habits such as opening bobby pins with the teeth, compulsive bruxism, nail biting and thread biting by seamstresses may also cause pulpal injury.

  In addition certain dental procedures occasionally injure the pulp.
- Accidental exposure of the pulp during excavation of carious tooth structure.
- Too-rapid movement of the teeth during orthodontic treatment.

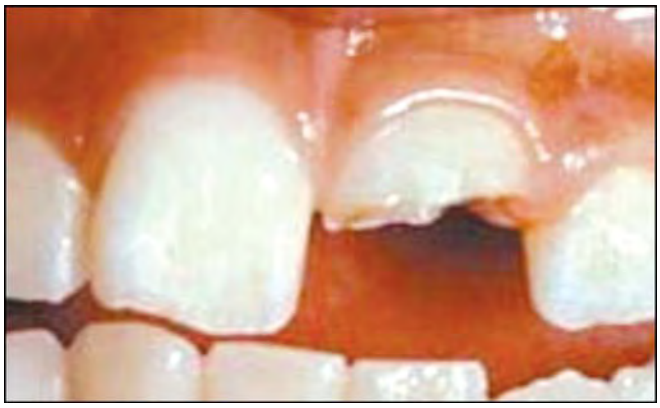


Fig. 2.2: Fractured anterior tooth

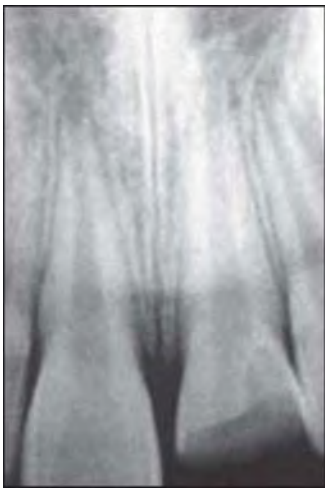


Fig. 2.3: Radiograph showing fractured anterior tooth

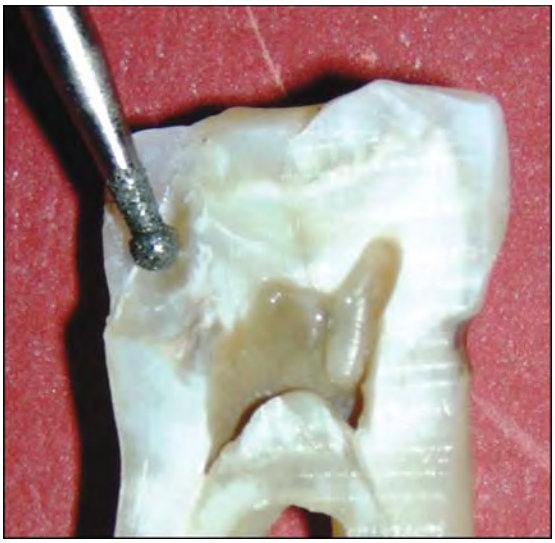


Fig. 2.4: Trauma to the pulp during cavity preparation

- Rapid separation of teeth by means of a mechanical separator.
- The use of pins for mechanical retention of amalgam or other restoration.
- Malleting of gold-foil filling without adequate cement base are among the iatrogenic causes of dental injuries.

During cavity preparation, the remaining dentin thickness should be between 1.1 and 1.5 mm to protect the pulp against inflammation and bacterial access (Fig. 2.4).

Dehydration of the pulp by a continuous air stream may cause aspiration of odontoblastic nuclei.

Dehydration may also be caused by restorative materials such as Cavit, which is hydrophilic and absorbs fluid from the dentinal tubules as it sets.

Pathologic Wear

The pulp may also become exposed or nearly exposed by pathologic wear of the teeth from either abrasion or attrition if secondary dentin is not deposited rapidly enough.

Cracked Tooth Syndrome

Incomplete fractures through the body of the tooth may cause pain of apparently idiopathic origin. This is referred to as the "cracked tooth syndrome". The patient usually complains of pain, ranging from mild to excruciating, at the initiation or the release of the biting pressure.

The most reliable diagnostic method is to try to reproduce the pain. When the patient bites on a cotton applicator or rubber wheel, the fracture segments may separate and the pain may be reproduced at the initiation or release of the biting pressure.

Barodontalgia

Barodontalgia, also known as aerodontalgia denotes toothache occurring at low atmospheric pressure experienced either during flight or during a test run in a decompression chamber.

A tooth with chronic pulpitis can be symptomless at ground level, but it may cause pain at high altitude because of reduced pressure. Lining the cavity with a varnish or Lining with Zinc oxide/Eugenol in deep cavities base of zinc-phosphate cement with a sub base of zinc oxide-Eugenol cement, helps to prevent Barodontalgia.

Radiation

Laser radiation sufficient to cause cavitations in teeth also causes severe degenerative changes in the pulp.

Pulpal Reaction to Fillings

Fillings made of silver amalgam, copper amalgam, silicate composites, and even oxyphosphate of zinc cement produce some pulp reaction when they are inserted into cavities prepared in dentin. The deeper the cavity, the greater is the damage caused, but in most cases the pulp recovers from the injury.

Thermal Injury

Thermal causes of pulp injury are uncommon.

Heat from Cavity Preparation (Fig. 2.5)

The chief offender is heat developed by a bur or diamond during cavity preparation. High-speed engines and carbide burs may reduce operating time, but they may also accelerate pulp death if they are used without a coolant. The heat generated may be sufficient to cause irreparable pulp damage.

Frictional Heat during Polishing

Enough heat may also be generated during polishing of a filling or during setting of cement to cause at least transient pulp injury.

Heat Conduction by Fillings (Fig. 2.6)

Metallic fillings close to the pulp without an intermediate cement base may conduct temperature changes rapidly to the pulp and may eventually destroy it. Sudden changes in temperature from foodstuffs, such as eating ice cream and drinking coffee, or chewing ice cubes, may also contribute to pulp injury

Chemicals

Chemical causes of pulp injury are probably the least common.

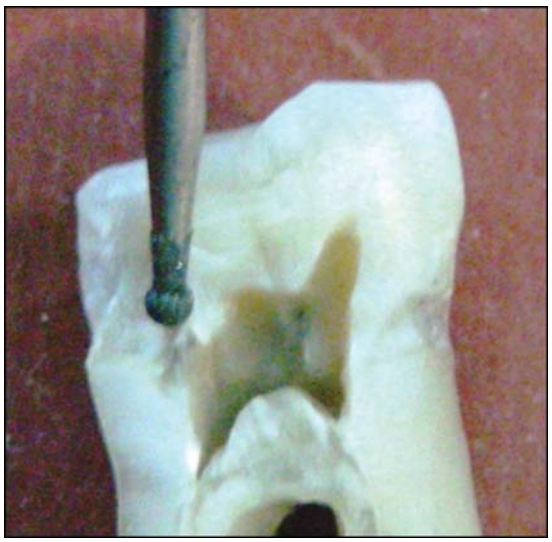


Fig. 2.5: Heat from cavity preparation

Fig. 2.6: Pulpal damage from fillings

Silicate restorations are the most frequent cause of pulp death in incisor teeth.

To protect the pulp one should use calcium hydroxide bases in deep cavities and calcium hydroxide liner in shallow cavities.

BACTERIA

In 1894, WD Miller suggested that bacteria were a possible cause of inflammation in the pulp. The most common cause of pulp injury is bacterial. Bacteria or their products may enter the pulp through a break in the dentin, either from caries or accidental exposure, from percolation around a restoration from extension of infection from the gingiva, or by way of the blood.

The presence or absence of bacterial irritation is the determining factor in pulp survival once the pulp has been mechanically exposed.

Once the bacteria have invaded the pulp the damage is almost always irreparable. The bacteria most often recovered from infected vital pulps are streptococci and staphylococci, but many other microorganisms, from diphtheroids to anaerobes, have also been isolated.

Pathways of Bacterial Invasion of the Pulp

Bacteria may enter the pulp in one of three ways:

1. Direct invasion by way of the dentin, such as caries, fracture of the crown or root, exposure during cavity preparation, attrition, abrasion, erosion, or crack in crown
2. Invasion through open blood vessels or lymphatics, associated with periodontal disease, an accessory canal in the furcation area, gingival infection, or scaling of teeth, and
3. Invasion through the blood, such as during infectious diseases or transient bacteremia.

Reactions of the Pulp to Bacterial Invasion

Once the pulp is exposed, either by caries or by trauma, it may be considered infected because microorganisms gain access to it almost immediately.

DISEASE OF THE PULP

Inflammation of the Pulp

Pulpitis or inflammation of the pulp may be acute or chronic, partial or total, and the pulp may be infected or sterile.

Classification

The diseases of dental pulp may be clinically classified as:

I. *Pulpitis (inflammation)*
   - A. Reversible
     1. Symptomatic (acute)
     2. Asymptomatic (chronic)
   - B. Irreversible pulpitis
     1. Acute
        - A. Abnormally responsive to cold
        - B. Abnormally responsive to heat
     2. Chronic
        - A. Asymptomatic with pulp exposure
        - B. Hyperplastic pulpitis
        - C. Internal resorption

II. *Pulp degeneration*
   - A. Calcific (radiographic diagnosis)
   - B. Others (histopathologic diagnosis)

III. *Necrosis*

REVERSIBLE PULPITIS (FIG. 2.7)

Definition

Reversible pulpitis is a mild to moderate inflammatory condition of the pulp caused by noxious stimuli in which the pulp is capable of returning to the uninflamed state following removal of the stimuli. Pain of brief duration may be produced by thermal stimuli in the reversible inflamed pulp, but the pain subsides as soon as the stimulus is removed.

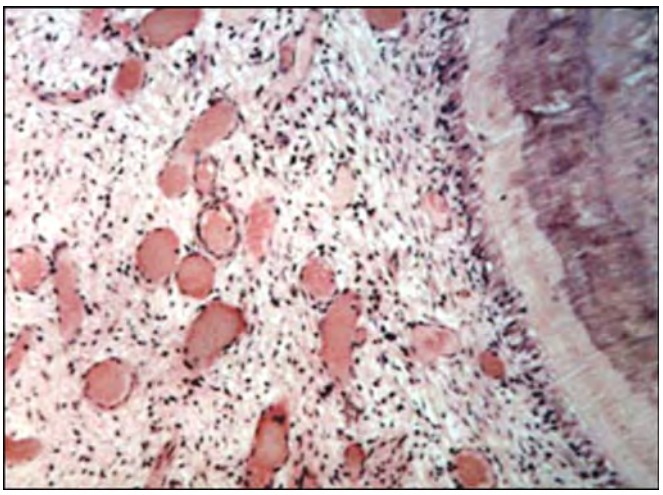


Fig. 2.7: Reversible pulpitis

Histopathology

Reversible pulpitis may range from hyperemia to mild to moderate inflammatory changes limited to the area of the involved dentinal tubules, such as dentinal caries.

Cause

Reversible pulpitis may be caused by any agent that is capable of injuring the pulp.

Specifically, the cause may be any of the following: trauma, as from a blow or from a disturbed occlusal relationship.

- Thermal shock, as from preparing a cavity with a dull bur or keeping the bur in contact with the tooth for too long.
- From overheating during polishing a filling.
- Excessive dehydration of a cavity with alcohol or chloroform.
- Irritation of exposed dentin at the neck of a tooth.
- Placement of a fresh amalgam filling in contact with, or occluding, a gold restoration.
- Chemical stimulus, as from sweet or sour foodstuffs
- Irritation of a silicate or self-curing acrylic filling.
- Bacteria, as from caries.

Following insertion of a restoration, patients often complain of mild sensitivity to temperature changes, especially cold, Such sensitivity may last 2 to 3 days or a week, or even longer, but it gradually subsides. This sensitivity is symptomatic of reversible pulpitis.

Circulatory disturbances, such as those accompanying menstruation or pregnancy, may also result in a transient periodic hyperemia.

Local vascular congestion associated with the common cold or with sinus disease can cause a generalized transient hyperemia of the pulp of the maxillary posterior teeth.

The irritant that cause hyperemia or mild inflammation in one pulp may produce secondary dentin in another, if the irritant is mild enough or if the pulp is vigorous enough to protect itself.

Symptoms

- Symptomatic reversible pulpitis is characterized by sharp pain lasting but a moment.
- It is more often brought on by cold than hot food or beverages and by cold air.
- It does not occur spontaneously and does not continue when the cause has been removed.
- The clinical differences between reversible and irreversible pulpitis is quantitative.
- The pain of irreversible pulpitis the pain may come without any apparent stimulus
- Asymptomatic reversible pulpitis may result from incipient caries and is resolved on removal of the caries and proper restoration of the tooth.

Diagnosis

Diagnosis is by a study of the patient's symptoms and by clinical tests.

The pain is sharp, lasts but a few seconds, and generally disappears when the stimulus is removed.

Cold, sweet, or sour usually causes symptoms.

The pulp may recover completely or the pain may last longer each time, and intervals of relief may become shorter, until the pulp finally succumbs.

Because the pulp is sensitive to temperature changes, particularly cold, application of cold is an excellent method of locating and diagnosing the involved tooth (Figs 2.8 and 2.9).

Fig. 2.8: Ice stick

Fig. 2.9: Carbon dioxide stick

A tooth with reversible pulpitis reacts normally to percussion, palpation, and mobility, and the Periapical tissue is normal on radiographic examination.

Differential Diagnosis

In reversible pulpitis, the pain is generally transitory, lasting a matter of seconds; whereas in irreversible pulpitis, the pain may last several minutes or longer.

The patient's description of the pain, particularly regarding its onset, character, and duration, is often of inestimable help in arriving at a correct differential diagnosis.

Thermal tests are useful in locating the affected tooth is unknown. The electric pulp test, using less current than on a control tooth, is an excellent corroborating test (Figs 2.10 to 2.12).

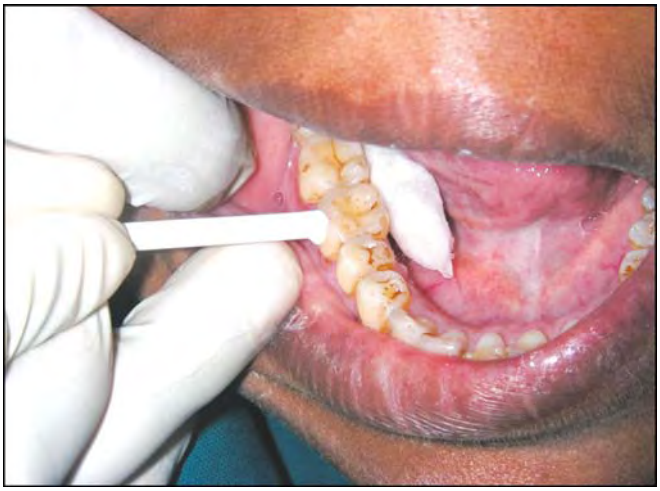


Fig. 2.10: Heat test hot gutta-percha

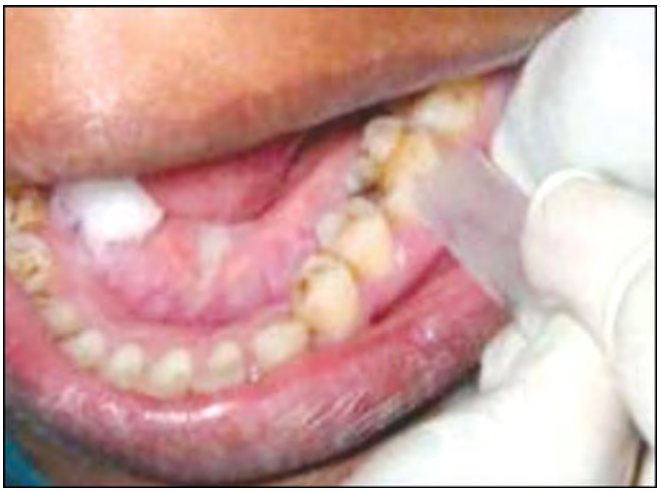


Fig. 2.11: Cold test with ice stick

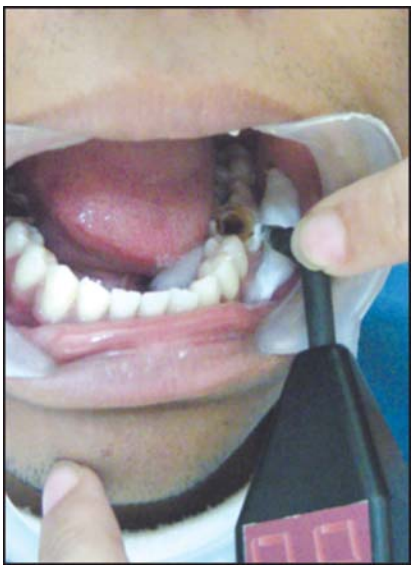


Fig. 2.12: Electric pulp testing

Treatment

"Prevention is better than cure"

- Periodic care to prevent the development of caries.
- Early insertion of a filling if a cavity has developed.
- Desensitization of the necks of teeth where gingival recession is marked.
- Use of a cavity varnish or cement base before insertion of a filling.
- Care in cavity preparation and polishing are recommended, to prevent pulpitis.
- When reversible pulpitis is present, removal of the noxious stimuli usually suffices.
- Once the symptoms have subsided, the tooth should be tested for vitality, to make sure that pulpal necrosis has not occurred.
- When pain persists despite proper treatment, the pulpal inflammation should be regarded as irreversible, the treatment for which is pulp extirpation.

Prognosis

The prognosis for the pulp is favorable if the irritant is removal early enough; otherwise, the condition may develop into irreversible pulpitis.

IRREVERSIBLE PULPITIS (FIG. 2.13)

Definition

Irreversible pulpitis is a persistent inflammatory condition of the pulp, symptomatic or asymptomatic, caused by a noxious stimulus.

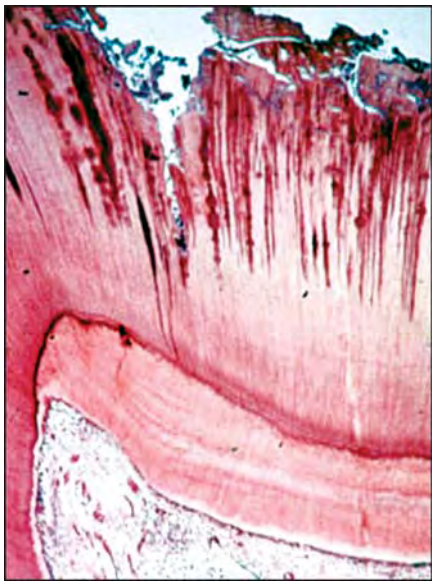


Fig. 2.13: Irreversible pulpitis

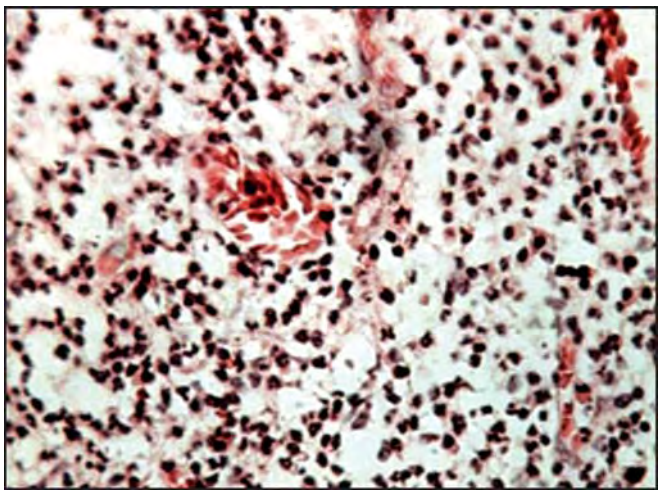


Fig. 2.14: Acute pulpitis

Acute irreversible pulpitis exhibits pain usually caused by hot or cold stimulus, or pain that occurs spontaneously. The pain persists for several minutes to hours, lingering after removal of the thermal stimulus (Fig. 2.14).

Histopathology

This disorder has chronic and acute inflammatory stages in the pulp. Irreversible pulpitis may be caused by a long-standing noxious stimulus such as caries.

Microscopically, one sees the area of the abscess and a zone of necrotic tissue, with microorganisms present if in the late carious state, along with lymphocytes, plasma cells, and macrophages.

No microorganisms are found in the center of the abscess because of the phagocytic activity of the polymorphonuclear leukocytes.

Histologically, one sees an area of necrotic tissue, a zone of infiltration by polymorphonuclear leukocytes, and a zone of proliferating fibroblasts forming the wall of the lesion, where calcific masses may be present.

The areas beyond the abscess or the ulceration may be normal or may undergo inflammatory changes.

Cause

The most common cause of irreversible pulpitis is bacterial involvement of the pulp through caries, although any clinical factor, chemical, thermal or mechanical, already mentioned as a cause of pulp disease may also cause pulpitis. As previously stated, reversible pulpitis may deteriorate into irreversible pulpitis.

Symptoms

In the early stages of irreversible pulpitis, a paroxysm of pain may be caused by the following; sudden temperature changes, particularly cold; sweet or acid foodstuffs; pressure from packing food into a cavity or suction exerted by the tongue or cheek; and recumbence, which results in congestion of the blood vessels of the pulp.

The pain often continues even when the cause has been removed and it may come and go spontaneously, without apparent cause, the patient may describe the pain as sharp piercing, or shooting, and it is generally severe.

It may be intermittent or continuous, depending on the degree of pulpal involvement and depending on whether it is related to an external stimulus.

The patient may also state that bending over or lying down, that is change of position, exacerbates the pain; changes in intrapulpal pressure may be the cause.

Changes in the blood pressure of the pulp may also occur. The patient may also have pain referred to adjacent teeth, to the temple or sinuses when an upper posterior tooth is involved, or to the ear when a lower posterior tooth is affected.

In later stages, the pain is more severe and is generally described as boring, gnawing, or throbbing, or as if the tooth was under constant pressure.

The pulp need not be macroscopically exposed, but a slight exposure is generally present, or else the pulp is covered with a layer of soft, leathery decay.

When no outlet is present, whether because of a covering of decay or a filling or because of food packed into a small exposure in the dentin, pain can be most intense.

Patients are often kept awake at night by the pain, which continues to be intolerable despite all their efforts at analgesia. Pain is increased by heat and is sometimes relieved by cold, although continued cold may intensify the pain.

After exposure and drainage of the pulp, pain may be slight, manifesting itself as a dull consciousness, or it may be entirely absent.

Pain can return if food packs into the cavity or underneath a leaky filling; it may not be as intense because of degeneration of the superficial nerve fibers.

Apical periodontitis is absent, except in the later stages, when inflammation or infection extends to the periodontal ligament.

Diagnosis

Inspection generally discloses a deep cavity extending to the pulp or decay under a filling. The pulp may already be exposed. On gaining access to the exposure, one may see a grayish, scum-like layer over the exposed pulp and the surrounding dentin.

The surface of the pulp is eroded. An odor of decomposition is frequently present in this area. Probing into the area is not painful to the patient until the deeper areas of the pulp are reached. At this level, both pain and hemorrhage may occur. If the pulp is not exposed by the carious process, a drop of pus may be expressed when one gains access to the pulp chamber.

Radiographic examination may not show anything of significance that is not already known clinically. It may disclose an interproximal cavity not seen visually, or it may suggest involvement of a pulp horn. A radiograph may also show exposure of the pulp, caries under a filling, or a deep cavity or filling threatening the integrity of the pulp in the early stages of irreversible pulpitis.

The thermal test may elicit pain that persists after removal of the thermal stimulus. In the late stages, when the pulp is exposed, it may respond normally to a thermal stimulus, but generally it reacts feebly to heat and cold.

The electric pulp test induces a response with a marked variation in current from the normal. Results of examination for mobility and percussion and palpation tests are negative.

Differential Diagnosis

One must distinguish between reversible and irreversible pulpitis. In reversible pulpitis, pain produced by thermal stimulus disappears as soon as the stimulus is removed, whereas in irreversible pulpitis, the pain lingers after the stimulus is removed, or it can occur spontaneously.

In the asymptomatic stage of irreversible pulpitis, the exposed pulp exhibits little or no pain, except when food is packed into the cavity.

More current is required to elicit a response to the electric pulp test than in a control tooth. In the early symptomatic stage, less current than normal is needed to elicit a response to the electric pulp tester, and the pulp is often abnormally responsive to cold stimulus. The induced or spontaneous pain that occurs is sharp, piercing, and readily identified with a specific tooth.

Other symptoms may develop, such as diffuse, dull, constant pain, characterized by throbbing and gnawing and the tooth may respond abnormally and severely to heat. This response generally is indicative of a later stage of irreversible pulpitis.

The pain of pulpitis is easy to localize by the patient at the onset. Once discomfort increases, the patient loses the ability to identify a particular tooth in the quadrant.

Treatment

Treatment consists of complete removal of the pulp, or pulpectomy, and the placement of an intracanal medicament to act as a disinfectant or obtundent, such as cresatin, eugenol, or formocresol.

Prognosis

The prognosis of the tooth is favorable if the pulp is removed and if the tooth undergoes proper endodontic therapy and restoration.

Differential diagnosis of reversible and irreversible pulpitis

	Reversible pulpitis	*Irreversible pulpitis*
1. History	Slight sensitivity or occasional pain	Constant or intermittent pain
2. Pain	- Momentary and immediate, sharp in nature and quickly/dissipates after	Continuous, delayed onset, throbbing, persists for minutes to hours after removal of stimulus
3. Location of pain	May be localized and is not referred	Pain is not localized if it is localized only after periapical involvement, pain is referred
4. Lying down (Change of posture)	No difference	Pain increases
5. Thermal test (Heat and Cold)	Responds	Markedly prolonged
6. EPT	Early response	Early, delayed or mixed response
7. Percussion	Negative	Negative in early stages, later positive when periapex is involved
8. Radiography	Negative	May shown widening of periodontal ligament space

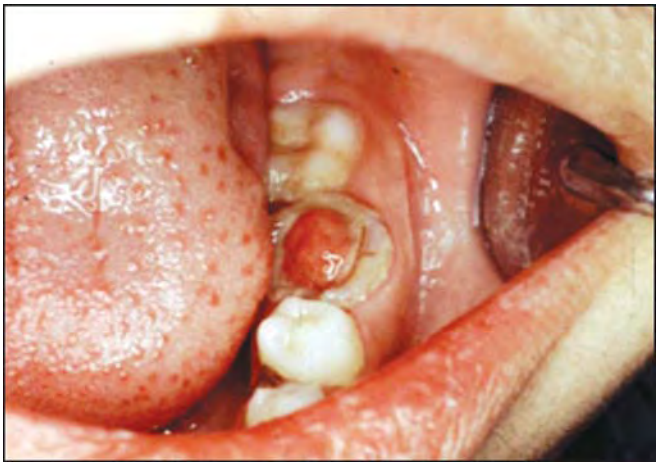


Fig. 2.15: Pulp polyp

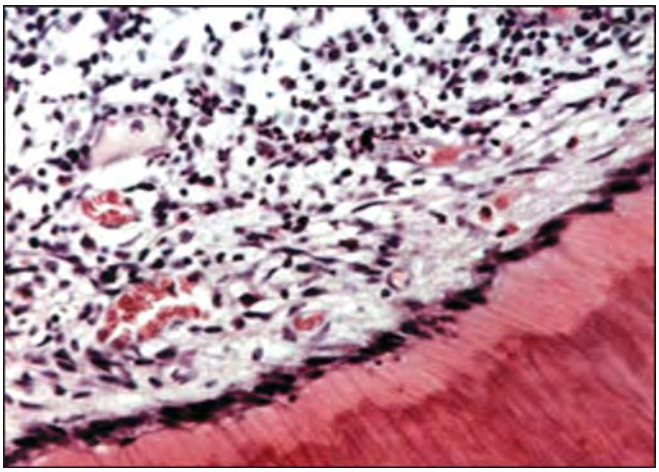


Fig. 2.16: Chronic hyperplastic pulpitis

CHRONIC HYPERPLASTIC PULPITIS (FIG. 2.15)

Definition

Chronic hyperplastic pulpitis or "pulp polyp" is a productive pulpal inflammation due to an extensive carious exposure of a young pulp.

This condition is characterized by the development of granulation tissue, covered at times with epithelium and resulting from long-standing, low-grade irritation.

Histopathology (Fig. 2.16)

Histopathologically, the surface of the pulp polyp is usually covered by stratified squamous epithelium.

The tissue in the pulp chamber is often transformed into granulation tissue, which projects from the pulp into the carious lesion.

Cause

Slow, progressive carious exposure of the pulp is the cause. For the development of hyperplastic pulpitis, a large, open cavity, a young, resistance pulp, and a chronic, low grade stimulus are necessary. Mechanical irritations from chewing and bacterial infection often provide the stimulus.

Symptoms

Chronic hyperplastic pulpitis is symptomless, except during mastication, when pressure of the food bolus may cause discomfort

Diagnosis

This disorder is generally seen only in the teeth of children and young adults. The appearance of the polypoid tissue is clinically characteristic; a freshy, reddish pulpal mass fills most of the pulp chamber or cavity or even extends beyond the confines of the tooth.

At times, the mass is large enough to interfere with comfortable closure of the teeth, although in the early stages of development it may be the size of a pin. Polypoid tissue is less sensitivity than normal pulp tissue and more sensitive than gingival tissue.

Cutting of this tissue produces no pain, but pressure thereby transmitted to the apical end of the pulp does cause pain.

This tissue bleeds easily because of a rich network of blood vessels. If the hyperplastic pulp tissue extends beyond the cavity of a tooth, it may appear as if the gum tissue is growing into the cavity.

To differentiate a pulp polyp from proliferating gingival tissue, one should raise and trace the stalk of the tissue back to its origin, the pulp chamber.

Radiographs generally show a large, open cavity with direct access to the pulp chamber. The tooth may respond feebly or not at all to the thermal test, unless one uses extreme cold, as from an ethyl chloride spray. More current than normal may be required to elicit a response by means of the electric pulp tester (Fig. 2.17).

Differential Diagnosis

The appearance of hyperplasic pulpitis is characteristic and should be easily recognized. The disorder must be distinguished from proliferating gingival tissue.

Treatment

Efforts at treatment should be directed toward elimination of the polypoid tissue followed by extirpation of the pulp, provided the tooth can be restored.

Prognosis

The prognosis for the pulp is unfavorable. The prognosis for the tooth is favorable after endodontic treatment and adequate restoration.

INTERNAL RESORPTION (FIG. 2.18)

Definition

Internal resorption is an idiopathic slow or fast progressive resorptive process occurring in the dentin of the pulp chamber or root canals of teeth.

Histopathology

Unlike caries, the internal resorption is the result of osteoclastic activity. The resorptive process is characterized by lacunae, which may be filled in by osteoid tissue. The osteoid tissue may be regarded as an attempt at repair.

Multinucleated giant cells or dentinoclasts are present. The pulp is usually chronically inflamed. Metaplasia of the pulp, that is, transformation to another type of tissue such as bone or cementum, sometimes occurs.

Cause

The cause of internal resorption is not known, but such patients often have a history of trauma.

Symptoms

Internal resorption in the root of a tooth is asymptomatic. In the crown of the tooth, Internal

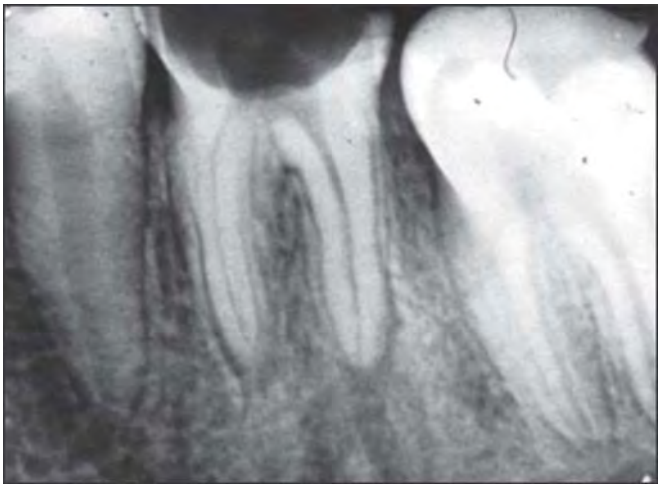


Fig. 2.17: Chronic hyperplastic pulpitis

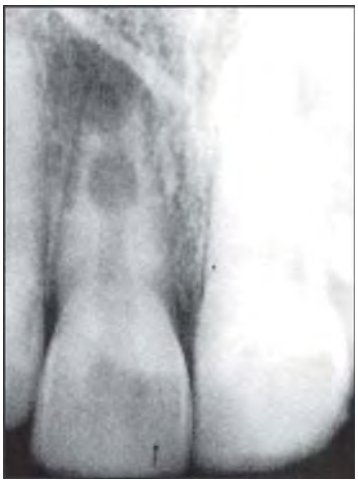


Fig. 2.18: Internal resorption

resorption may be manifested as a reddish area called "pink spot" this reddish area represents the granulation tissue showing through the resorbed area of the crown.

Diagnosis

Internal resorption may affect either the crown or the root of the tooth, or it may be extensive enough to involve both. Although any tooth in the mouth can be involved, those most readily recognized are the maxillary anterior teeth.

The appearance of the "pink spot" occurs late in the resorptive process, when the integrity of the crown has been compromised.

The radiograph usually shows a change in the appearance of the wall in the root canal or pulp chamber, with a round or ovoid radiolucent area.

Differential Diagnosis

When internal resorption progresses into the periodontal space and a perforation of the root occurs, it is difficult to differentiate from external resorption. In internal resorption, the resorptive defect is more extensive in the pulpal wall than on the roof surface; this defect usually is recognized by means of a radiograph.

Treatment

Extirpation of the pulp stops the internal resorptive process. Routine endodontic treatment is indicated.

Prognosis

The prognosis is best before perforation of the root crown occurs. In the event of a root-crown perforation, the prognosis is guarded and depends on the formation of a calcific barrier or access to the perforation that permits surgical repair.

PULP DEGENERATION

Although degeneration of the pulp, as such, is seldom recognized clinically, the types of pulp degeneration should be included in a description of diseases of the pulp. Degeneration is generally present in the teeth of older people.

Degeneration may also be the result of persistent, mild irritation in teeth of younger people, however, as in calcific degeneration of the pulp. The specific types of pulp degeneration are:

Calcific Degeneration

In calcific degeneration, part of the pulp tissue is replaced by calcific material; that is, pulp stones or denticles are formed. This calcification may occur either within the pulp chamber or root canal, but it is generally present in the pulp chamber. Dystrophic calcification may occur at the apical canal openings, where coagulation necrosis attracts calcium salts from the surrounding environment. This is similar to calcification subjacent to layers of coagulation necrosis produced by caustic pulp-capping agents,

The calcified material has a laminated structure, like the skin of an onion, and lies unattached within the body of the pulp. Such a denticle or pulp stone may become large enough to give an impression of the pulp cavity when the calcified mass is removed, in another type of calcification, the calcified material is attached to the wall of the pulp cavity and is an integral part of it. It is not always possible to distinguish one type from another on a radiograph.

Pulp Stones (Fig. 2.19)

It is estimated that pulp stones are present in more than 60 percent of adult teeth. They are considered to be harmless concretions, although referred pain in a few patients has been ascribed to the presence of these calcifications in the pulp.

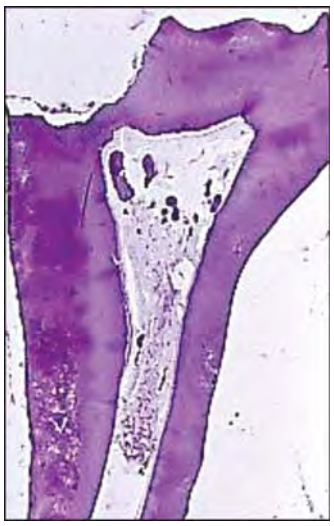


Fig. 2.19: Pulp stones

Pulp stones can be classified according to:

Position { Free, Attached, Embedded

Structure { True, False

1. *According to position:*
   - *Free pulp stones:* These pulp stones lie freely in the pulp tissue (Fig. 2.20)
   - *Attached pulp stone:* These pulp stones are attached to the dentinal wall (Fig. 2.21)
   - *Embedded pulp stone:* These pulp stones are encircled by dentine (Fig. 2.22)

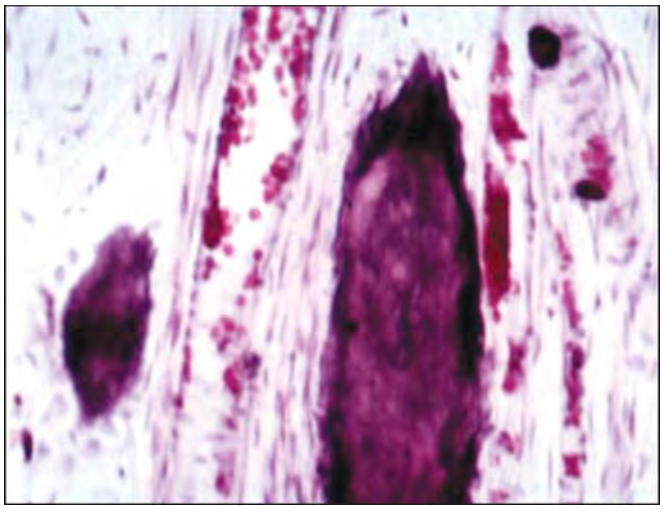


Fig. 2.20: Free pulp stone

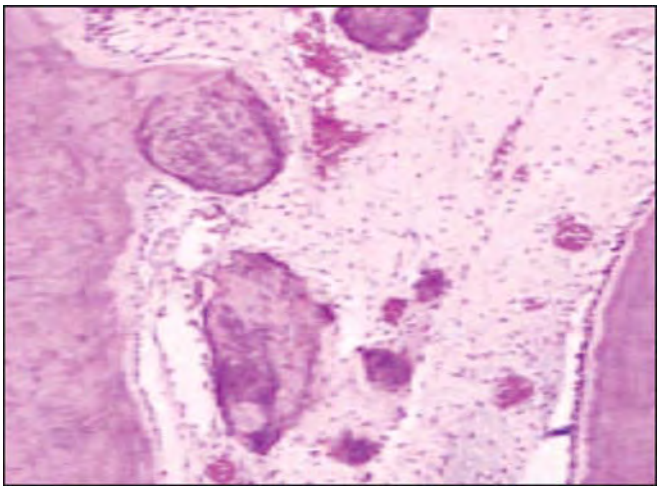


Fig. 2.21: Attached pulp stone

Fig. 2.22: Embedded pulp stone

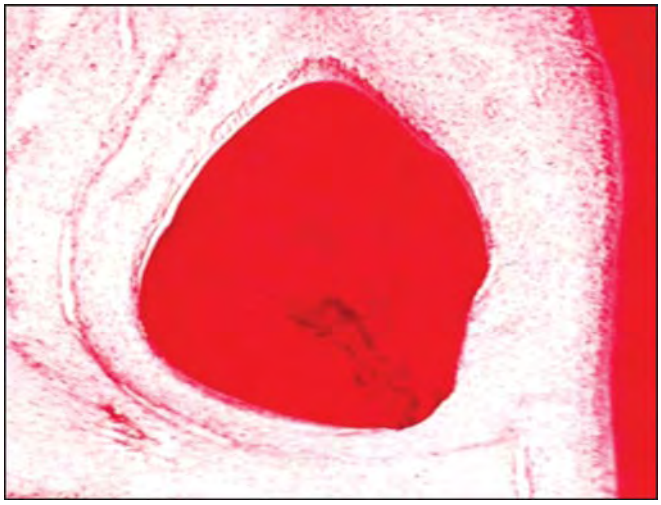


Fig. 2.23: True pulp stone

2. *According to structure:*
   - *True pulp stone:* These pulp stones are similar to dentine having dentinal tubules and odontoblasts (Fig. 2.23)
   - *False pulp stone:* They are calcified masses arranged in lamellar fashion around a nidus and they do not contain dentinal tubules (Fig. 2.24).

Atrophic Degeneration

In this type of degeneration, observed histopathologically in pulps of older people, fewer stellate cells are present, and intercellular fluid is increased. The pulp tissue is less sensitive than normal.

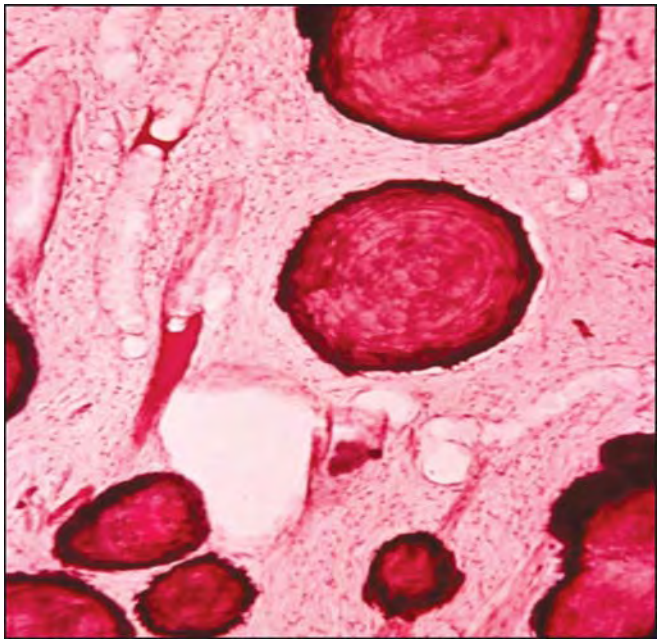


Fig. 2.24: False pulp stone

Fibrous Degeneration

This form of degeneration of the pulp is characterized by replacement of the cellular elements by fibrous connective tissue. On removal from the root canal, such a pulp has the characteristic appearance of a leathery fiber. This disorder causes no distinguishing symptoms to aid in the clinical diagnosis.

Tumor Metastasis

Metastasis of tumor cells to the dental pulp is rare, except possibly in terminal stages.

NECROSIS OF PULP (FIG. 2.25)

Definition

Necrosis is death of the pulp it may be partial or total, depending on whether part of or the entire pulp is involved. Necrosis, although a sequel to inflammation, can also occur following a traumatic injury in which the pulp is destroyed before an inflammatory reaction takes place.

As a result, an ischemic infarction can develop and may cause a dry gangrenous necrotic pulp. Necrosis is of two general types: coagulation and liquefaction.

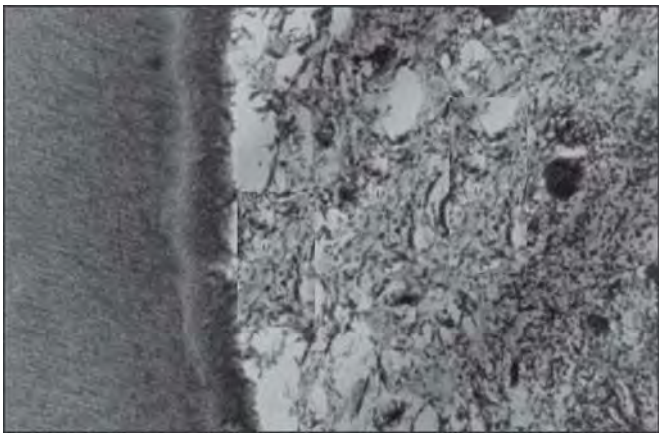


Fig. 2.25: Pulp necrosis

Cause

Necrosis of the pulp can be caused by any noxious insult injurious to the pulp, such as bacteria, trauma, and chemical irritation.

Symptoms

An otherwise normal tooth with a necrotic pulp causes no painful symptoms. Frequently, discoloration of the tooth is the first indication that the pulp is dead. The dull or opaque appearance of the crown may be due merely to a lack of normal translucency.

Teeth with partial necrosis can respond to thermal changes, owing to the presence of vital nerve fibers passing through the adjacent inflamed tissue.

Diagnosis

Radiograph generally shows a large cavity or filling, an open approach to the root canal, and a thickening of the periodontal ligament, Some teeth have neither a cavity nor a filling, and the pulp has died as a result of trauma a few patients have a history of severe pain lasting from a few minutes to a few hours, followed by complete and sudden cessation of pain.

A tooth with a necrotic pulp does not respond to cold, the electric pulp test, or the test cavity. In rare cases, however, a minimal response to the maximum current of an electric pulp tester occurs when the electric current is conducted through the moisture present in a root canal following liquefaction necrosis to neighboring vital tissue.

PERIAPICAL DISEASES

There is a pathway between pulp and periradicular area. When pulp is infected, it contains bacterial, toxins and immunological factors. These first appear in pulp and slowly seep by various ways to periradicular area causing following diseases.

1. Apical periodontitis
2. Alveolar abscess
3. Radicular cyst
4. Periapical granuloma
5. Cementoma
6. Condensing osteitis
7. Ossifying fibroma

WHO Classification of the diseases of the periapex (1995):

K04.4 - Acute apical periodontitis
K04.5 - Chronic apical periodontitis (apical granuloma)
K04.6 - Periapical abscess with sinus (dentoalveolar or periodontal abscess with pulpal origin)
K04.60 - Periapical abscess with sinus into maxillary antrum
K04.61 - Periapical abscess with sinus into nasal cavity
K04.62 - Periapical abscess with sinus into oral cavity
K04.63 - Periapical abscess with sinus to skin
K04.7 - Periapical abscess without sinus
K04.8 - Radicular cyst (Apical periodontal cyst, periapical cyst)
K04.80 - Apical and lateral cyst
K04.81 - Residual cyst
K04.82 - Inflammatory paradental cyst

Apical Periodontitis

Apical periodontitis is a localized inflammation of the periodontal ligament in the apical region. Apical periodontitis is classified as symptomatic or asymptomatic periodontitis. Depending on the duration. It can also be classified as acute and chronic.

Causes

- Irritants diffusing from an inflamed or necrotic pulp.
- Bacteria, bacterial toxins
- Disinfecting medications
- Debris pushed into the periradicular tissues
- Physical irritation of the periapical tissues
- Impact trauma

Clinical Features

- Pain varies from slight tenderness to excruciating pain on mastication
- Tenderness on vertical percussion is present.
- Tooth may or may not respond to vitality tests.

Histopathology

There is a exudation of inflammatory cells from the blood vessels into the periradicular tissues. Breakdown of the periodontal ligament and resorption of the alveolar bone due to the release of inflammatory mediators.

Alveolar Abscess

Alveolar abscess is the collection of the pus at the tip of the root.

Depending on the duration of the onset, alveolar abscess can be divided into:

- Acute
- Chronic.

Signs and Symptoms

- Pain
- Swelling
- Fever
- G1 tract disturbance

It is difficult to diagnose and acute alveolar abscess by radiographic findings alone. However in chronic cases the radiographs show diffuse radiolucency.

Histologically, there will be presence of leucocytic infiltration depending on the type of the disease.

On clinical examination the tooth is non-vital.

Radicular Cyst (Dental Cyst or Periapical Cyst)

Cyst is a closed cavity containing fluids and semisolid material in the center surrounded by epithelial cells.

Small cysts will not be noticed with ease clinically. Large cysts have apparent swelling with cracking sound of the bone on palpation. During expansion cyst will push the roots apart.

Radiographic Features (Fig. 2.26)

It has a well defined radiolucency with radiopaque lining. It is larger than granuloma.

Definite diagnosis is possible by histopathology which shows cholesterol crystals in cystic fluid seen under microscope.

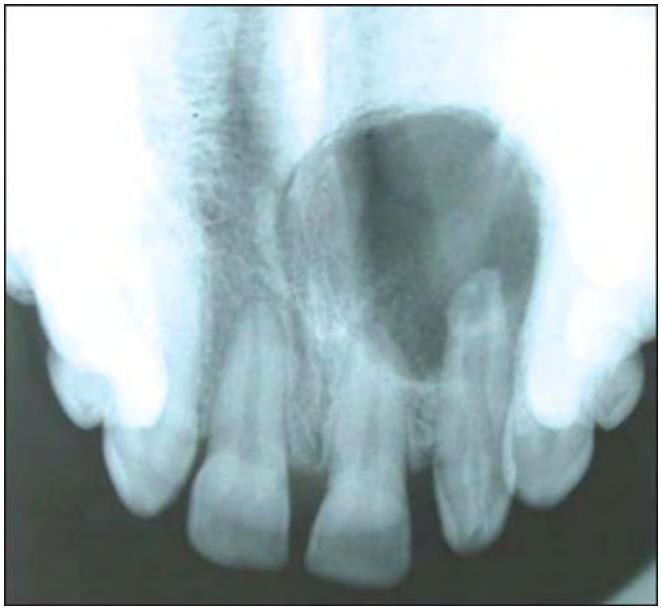


Fig. 2.26: Radiographic findings of radicular cyst

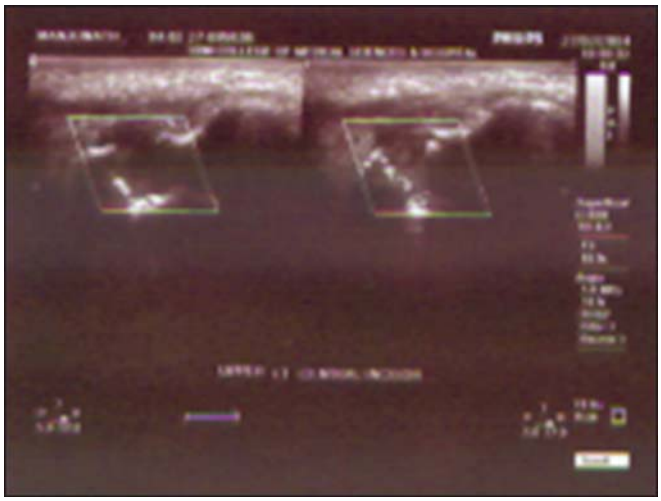


Fig. 2.27: Ultrasonographic finding of radicular cyst

Recently, non-invasive methods like echography and CT scan are used in the diagnosis (Fig. 2.27).

Histopathology (Fig. 2.28)

Histologic examination of a radicular cyst shows a central cavity lined by stratified squamous epithelium. The lumen contains a pale yellow fluid or semisolid material and occasionally some cellular debris. The connective tissue shows the cellular and extracellular elements of the periradicular granuloma. Inflammatory cells are present within the epithelial lining of this lesion.

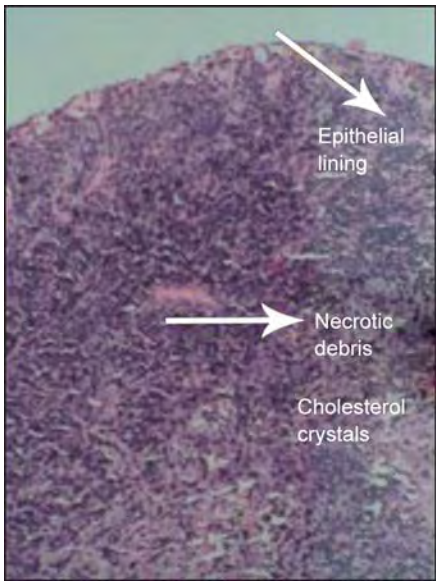


Fig. 2.28: Histopathology of radicular cyst

Periapical Granuloma

It is a granulation tissue at the apex of the tooth. Granulation tissue results at the apex due to chronic low grade irritation to the Periapical tissues due to microorganisms, toxins and byproducts of tissue breakdown.

Clinical findings - tooth is non-vital.

As the size of the granuloma is smaller than the cyst. Swelling is not apparent in the vestibular area or alveolus.

Radiographic Findings (Figs 2.29 and 2.30)

It is well defined radiolucency which is round in shape with definite borders.

Histopathology (Fig. 2.31)

The periapical granuloma consists of small capillaries, granulation inflammatory tissue with many fibroblasts, connective tissue fibers, and usually a connective tissue capsule. There is a infiltration of by plasma cells, lymphocytes, mononuclear phagocytes, and occasional neutrophils.

Cementoma

(Periradicular cemental dysplasia) is considered as benign fibrous osseous lesion rather than benign tumor. Cause is unknown. Heredity plays an important role.

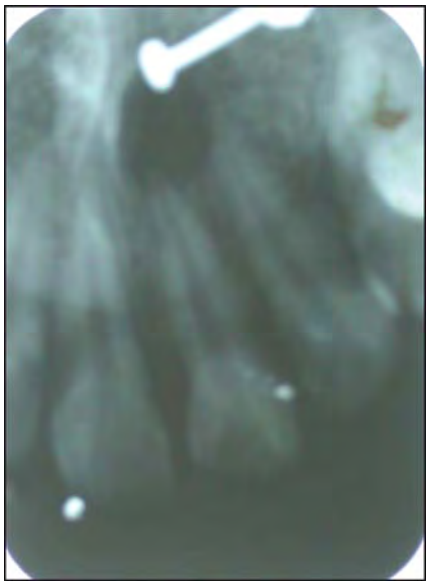


Fig. 2.29: Radiographic finding of periapical granuloma

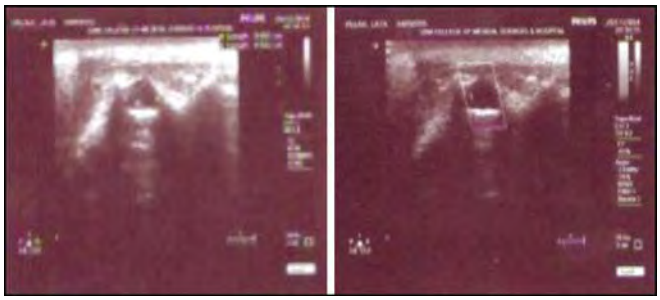


Fig. 2.30: Ultrasonographic finding of periapical granuloma

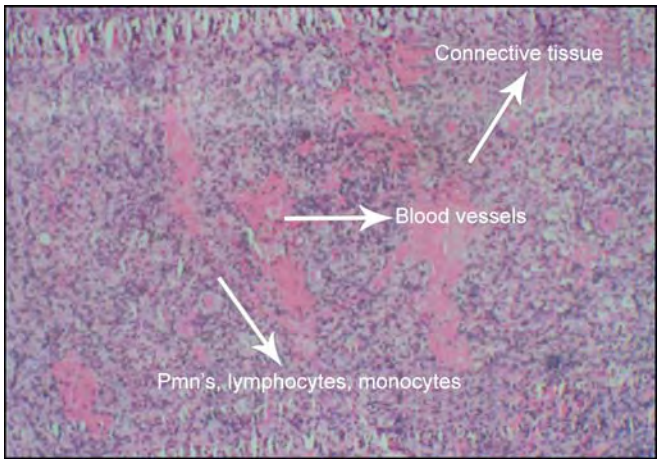


Fig. 2.31: Histopathology finding of periapical granuloma

Clinical Features

It is common in mandible particularly in the incisor area.

Lesion is single or multiple, commonly in women.

Clinically - Tooth is vital.

Radiographical Features

There are three different radiographic features for this lesion-

Radiolucent, Radiopaque and mixed appearance.

Condensing Osteitis

This is a focal sclerosing osteomylites clinically, it is due to chronic pulpal pathology. The tooth is non-vital on clinical examination. Radiographically presents as radiopacity around the apex of the tooth.

Ossifying Fibroma

It is just like cementoma. It occurs at the apex of vital teeth more commonly in mandibular.

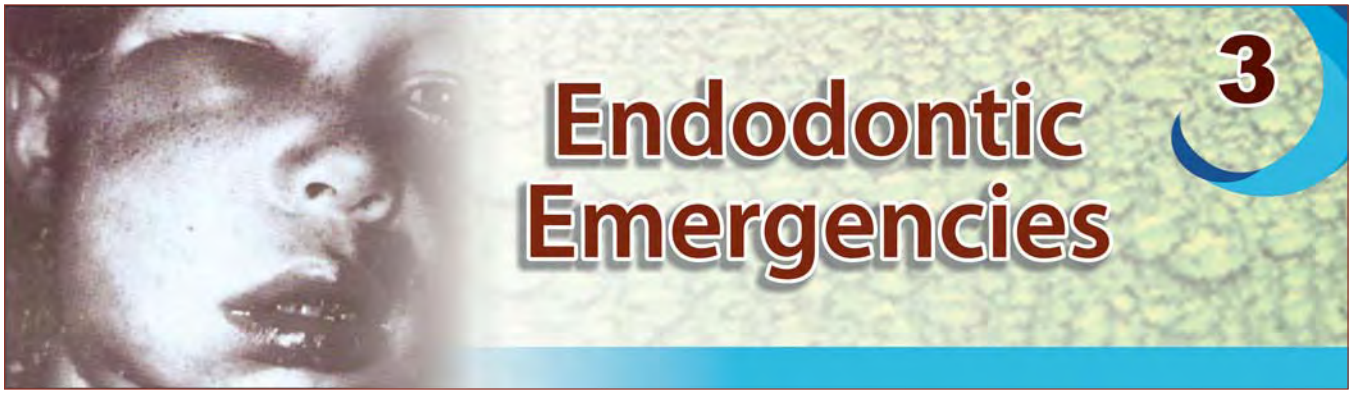
The differences are:

- It occurs in young people
- May reach a large size causing expansion of mandible.

SUGGESTED READING

1. Baume LJ. Diagnosis of diseases of the pulp. Oral Surg Oral Med Oral Pathol 1970;29:102-16.
2. Byers MR, Narhi MV, Mecifi KB. Acute and chronic-reactions of dental sensory nerve fibers to hydrodynamic stimulation or injury. Anat Rec 1988;221: 872-83.
3. Barbakow F, Cleaton-Jones P, Friedman D. Endodontic-treatment of teeth with periapical radiolucent areas in ageneral practice. Oral Surg Oral Med Oral Pathol 1981;51: 552-59.
4. Bender IB. Reversible and irreversible painful pulpitides: diagnosis and treatment. Aust Endod J 2000;26:10-14.
5. Byers MR, Narhi MVO. Dental injury models: Experimental tools for understanding neuroinflammatory interactions and polymodal nocicpetor functions. CritRev Oral Biol Med 1999;10: 4-39.
6. Casasco A, et al. Peptidergic nerves in human dental pulp: An immunocytochemical study. Histochemistry 1990;95:115-21.
7. Ciprofloxacin, metronidazole and minocycline. Int EndodJ 1996;29:125-30.
8. Dubner R, Ruda MA. Activity-dependent neuronal-plasticity following tissue injury and inflammation. Trends Neurosci 1992;15: 96-103.
9. Dummer PMH, Hicks R, Huws D. Clinical signs and symptoms in pulp disease. Int Endod J 1980;13:27-35.

10. Fulling HJ, Andreasen JO. Influence of maturation status and tooth type of permanent teeth upon electrometric and thermal pulp testing procedures. Scand J Dent Res 1976;84:291-96.
11. Garfunkel A, Sela J, Almansky M. Dental pulp pathosis: Clinicopathologic correlation based on 109 cases. Oral Surg Oral Med Oral Pathol 1987;35:110-17.
12. Heide S, Mjo¨r IA. Pulp reaction to experimental exposures in young permanent monkey teeth. Int EndodJ 1983;16: 11-19.
13. Hasler JE, Mitchell DF. Painless pulpitis. J Am DentAssoc 1970;81: 671-7.
14. Hirvonen T, Hippi P, Narhi M. The effect of an opioidantagonist and a somatostatin antagonist on the nerve function in normal and inflamed pulp. J Dent Res 1998;77(abstract): 1329.
15. Hoshino, et al. *In vitro* antibacterial susceptibility of bacteria taken from infected root dentine to a mixture of Pulpal diagnosis.
16. Jyvasjarvi E, Kniffki DK. Cold stimulation of teeth: a comparison between the responses of cat intradental A - and C- fibers and human sensations. J Physiol 1987;391: 193-207.
17. Lundy T, Stanley HR. Correlation of pulpal histopathology and clinical symptoms in human teeth subjected to experimental irritation. Oral Surg Oral Med Oral Pathol 1969;27:187-201.
18. Michaelson PL, Holland GR. Is pulpitis painful? IntEndod J 2002;35: 829-32.
19. Morse DR, Seltzer S, Sinai I, Biron G. Endodontic classification. J Am Dent Assoc 1977;94:685-89.
20. Narhi MVO, Hirvonen T, Hakumaki MOK. Activation of intradental nerves in the dog to some stimuli applied to the dentin. Arch Oral Biol 1982;27:1053-58.
21. Narhi MVO, Yamamoto H, Ngassapa D, Hirvonen T. Function of interadental nociceptors in normal an inflamed teeth. In: Shjimono M, Maeda T, Suda H,Takahashi K, (Eds). Dentin/pulp Complex. Tokyo: Quintessence Publ. 1996;136-40.
22. Olgart LM. Neural control of pulpal blood flow. Crit Rev Oral Biol Med 1996;7:159-71.
23. Seltzer S. Classification of pulpal pathosis. Oral Surg Oral Med Oral Pathol 1972;34:269-80.
24. Seltzer S, Bender IB, Zionitz M. The dynamics of pulp inflammation: correlation between diagnostic data and actual histologic finding in the pulp. Oral Surg Oral Med Oral Pathol 1963;16:846-71.
25. Sigurdsson A, Maixner W. Effects of experimental and clinical noxious counter irritants on pain perception. Pain 1994;57:265-75.
26. Taddese A, Nah S-Y, McClesky EW. Selective opioid inhibition of small nociceptive neurons. Science 1995;270:1366-69.



Definition

Endodontic emergencies are circumstances associated primarily with pain and/or swelling that requires immediate diagnosis and treatment.

Most of the emergencies are unscheduled.

The reason for endodontic emergency treatment is pain and swelling from pulpoperiapical pathosis.

Classification

I. Pre-endodontic emergencies
II. Emergencies during treatment/inter appointment flare ups
III. Post-endodontic emergencies.

Pre-endo-emergencies

- Acute reversible pulpitis
- Acute irreversible pulpitis
- Acute apical periodontitis
- Acute alveolar abscess
- Acute periodontal abscess
- Cracked tooth syndrome
- Crown fracture
- Root fracture
- Tooth Avulsion
- Referred pain

Emergencies During Endodontic Treatment

- Vital pulp tissue remnants
- Improper irrigation
- Over instrumentation

Post-endodontic-emergencies

- Vertical fracture
- Over obturation
- Under obturation

ACUTE REVERSIBLE PULPITIS (HYPEREMIA)

Definition

- It is a mild-to-moderate inflammatory condition of the pulp caused by noxious stimuli in which the pulp is capable of returning to the uninflamed state following removal of the stimulus.
- It is characterized by sharp pain lasting but a moment, more often brought on by cold than hot food or beverages.
- The patient can identify the tooth.
- Momentary pain that subsides on removal of stimulus.

Causes

- Trauma as from a blow or from a disturbed occlusal relationship.
- Thermal shock as from preparing a cavity with a dull bur or keeping the bur in contact with the tooth long or from over heating during polishing a filling.
- Excessive dehydration of a cavity with alcohol or chloroform, or irritation of exposed dentin at the neck of a tooth.
- Placement of a fresh amalgam filling in contact with, or occluding a gold restoration.

- Chemical stimulus as from sweet or sour food stuffs OR from irritation of a silicate or self-curing acrylic filling.
- Bacterial as from caries.

Treatment

The best treatment is prevention.

- In recently restored teeth occlusion is adjusted.
- In cases of marginal leakage or secondary caries, the old restorations are removed and replaced with sedative cement.
- Pain usually disappears within several days, if it persists then pulp has to be extirpated.

ACUTE IRREVERSIBLE PULPITIS

Definition

It is a persistent inflammatory condition of the pulp, symptomatic or asymptomatic, caused by a noxious stimulus. Acute irreversible pulpitis exhibits pain usually caused by hot or cold stimulus.

- The pain is sharp, piercing or shooting and it is generally severe.
- Abnormally responsive to heat and cold
- Pain occurs spontaneously
- Pain lasts for several minutes to hours and lingers even after removal of stimulus
- Nocturnal pain, pain on bending or lying down position.

Treatment

Pulpectomy

The procedure is as follows:

- Anesthetize
- Access cavity prepared and canals located
- Extirpate the canals
- Cleaning and shaping with the use of irrigating solution like sodium hypochlorite. Pain persists if inflamed pulp remains in root canal because inflammatory process will extend into peri-radicular tissues
- Closed dressing given and occlusion relieved.

ACUTE APICAL PERIODONTITIS

Definition

It is a painful inflammation of periodontium as a result of trauma, irritation or infection through root canal whether the pulp is vital or non-vital.

Causes

- Occlusal trauma
- Wedging of foreign objects
- Blow to tooth
- Inflammation from the pulp extending to periodontium (dental caries/trauma).
- Over instrumentation or over filling.

Symptoms

Pain and tenderness of the tooth, sometimes the tooth may be extruded.

Treatment

Vital tooth—symptomatic treatment
Non-vital tooth—Root canal therapy

ACUTE ALVEOLAR ABSCESS (FIG. 3.1)

Definition

It is a localized collection of pus in the alveolar bone at the root apex following pulp death with extension of infection through apical foramen into periapical tissues.

The symptoms can be divided into:

1. Localized
   a. Swelling
   b. Asymmetry of the face
   c. Pain
2. Systemic
   a. Elevated temperature
   b. Dizziness
   c. Malaise

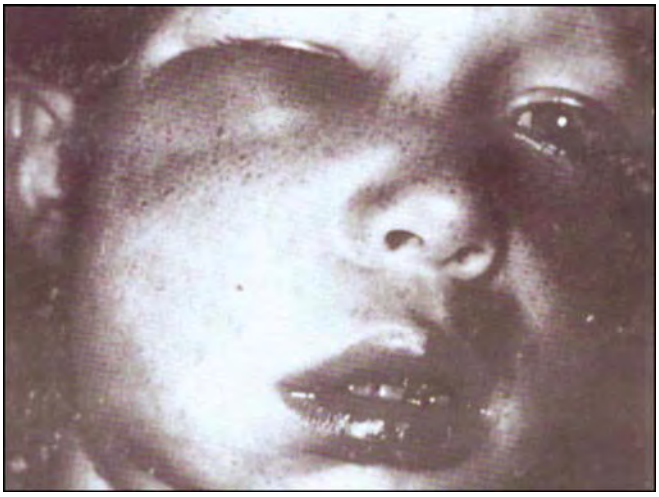


Fig. 3.1: Acute alveolar abscess

d. Nausea
e. Lack of sleep
f. Headache

Treatment

- Removal of necrosed pulp,
- Cleaning and shaping of root canal, placement of calcium hydroxide.
- Obturation of the root canal in the next visit
- These steps will restore the tooth to functional health.

Precautions to be taken

1. During root canal treatment local anesthesia should not be infiltrated into the swelling, as infection can spread into various facial spaces and may cause additional pain due to the increase in the amount of liquid in the swelling. The anesthetic agent injected into the swelling, also will have no effect because of the reduced pH.
   This can be prevented by injecting anesthesia away from the swelling. In such cases nerve blocks are preferred.
2. In acute alveolar abscess, the tooth has mobility. So during access cavity preparation, the tooth should be stabilized to reduce the pain.
   The tooth can be stabilized with the help of fingers or with the impression compound. However, the impression compound can cause increased pain due to the heat.

With Swelling

There are three ways to resolve it:
1. Establish drainage through root canal
2. Establish drainage by incising a fluctuant swelling (if the swelling is hard, rinse it 3-5 mins with hot saline)
3. Use of antibiotics is regarded as an aid to drainage.

INCISION AND DRAINAGE

Incise at the site of greatest fluctuance.

The clinician should dissect gently through deeper tissues and thoroughly explore all parts of abscess cavity.

To promote drainage, the wound should be kept clean with warm water mouth rinses.

In cases where periapical drainage cannot be established, surgical Trephination is done.

Definition

Trephination is the surgical perforation of alveolar cortical plate (over the root end) to release the accumulated tissue exudate that is causing pain.

(A small vertical incision is made adjacent to the tooth, the mucosa is retracted and No. 6 round bur is used to penetrate cortical plate. This provides drainage.)

Recent technique involves use of engine driven perforator to enter the medullary bone without the need of incision.

ACUTE PERIODONTAL ABSCESS

Pain and Swelling

It is usually mistaken for acute alveolar abscess (Fig. 3.2).

It may occur with vital or necrosed pulp, but its origin is usually an exacerbation of infection with pus formation in an existing deep infra bony pocket.

Differences

Acute apical abscess	*Acute periodontal abscess*
Origin-pulp	Periodontal
Non-vital	Vital
No bone loss	Bone loss
Lesion is at the apex	Laterally placed
Tender on vertical percussion	Tender on horizontal percussion
No pocket	Infra bony pocket

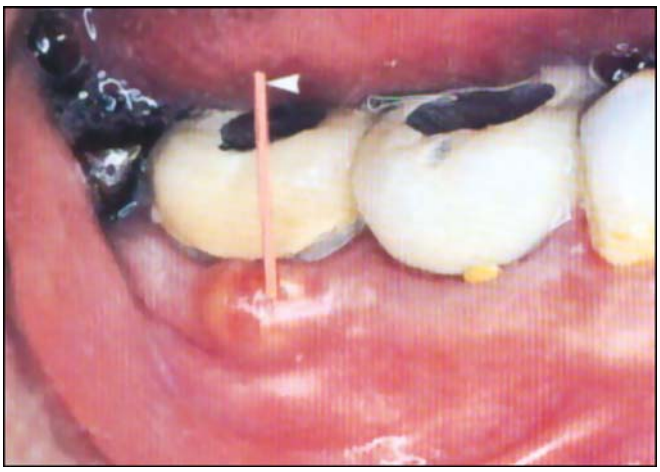


Fig. 3.2: Gutta-percha tracing

If pulp is vital, treatment is curettage, debridement, establishment of drainage, through sulcular crevice.

If the pulp is non-vital, root canal therapy should be carried out.

CRACKED TOOTH SYNDROME/ CROWN FRACTURE

Definition

Incomplete fractures through the body of the tooth may cause pain of apparently idiopathic origin and this is referred to as cracked tooth syndrome.

The patient usually complains of pain ranging from mild to excruciating at the initiation or release of biting pressure

Diagnosis

a. By reproducing the pain (Figs 3.3 and 3.4)
   When the patient bites on cotton applicator or rubber wheel, fracture segments may separate and the pain may be produced at the initiation or release of biting pressure.
b. By transillumination
c. Use of dyes.

Treatment

- Immediate reduction of offending cusps by selective grinding
- If dentine is exposed, sedative cement is placed and a stainless steel band is cemented.

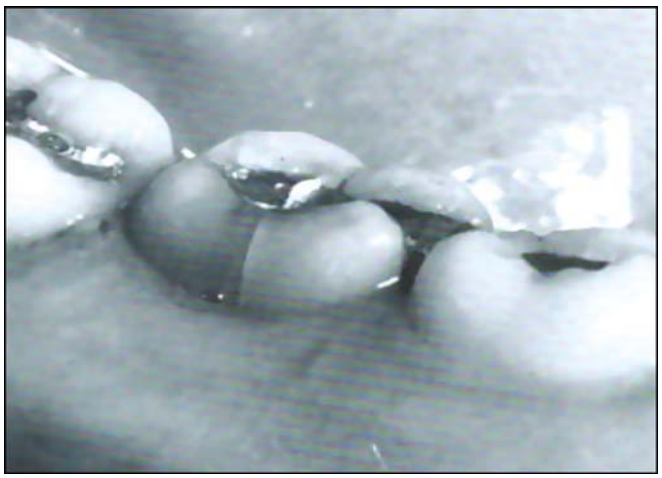


Fig. 3.3: Cracked tooth

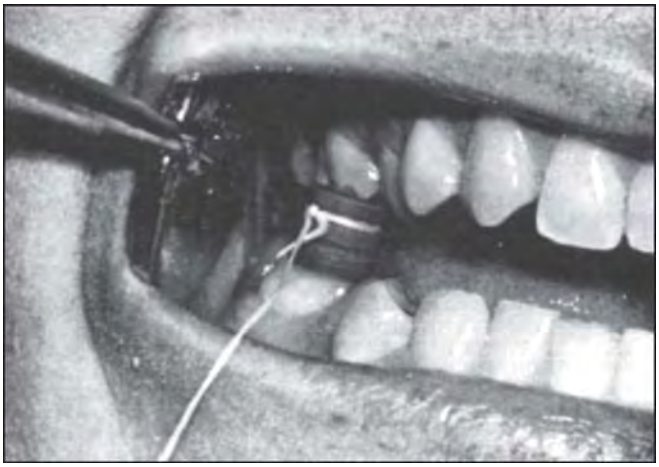


Fig. 3.4: Biting on rubber wheel

- Definitive treatment is to preserve vital pulp by full crown
- Irreversible pulpitis - Root canal therapy

ROOT FRACTURE

1. Horizontal root fracture:
   a. At apical third (Fig. 3.5)
   b. In the middle third (Fig. 3.6)
   c. In the cervical third (Fig. 3.7)
2. Vertical root fracture (Fig. 3.8)

Prognosis

Depends on location and direction of fracture.

A horizontal fracture above the alveolar crest has excellent prognosis since the tooth can be restored.

Apical root fracture - favorable prognosis.

Fracture of middle third - Poor prognosis.

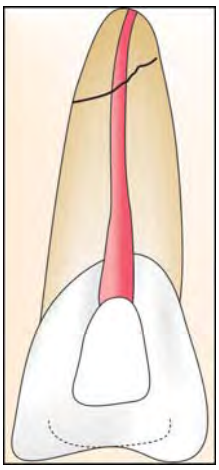


Fig. 3.5: Root fracture at apical third

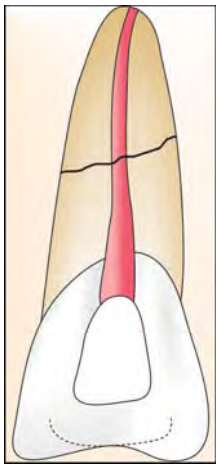


Fig. 3.6: Root fracture in the middle third

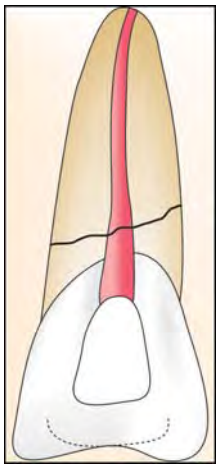


Fig. 3.7: Root fracture in the cervical third

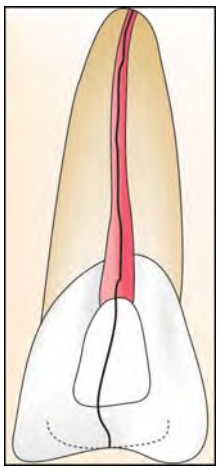


Fig. 3.8: Vertical root fracture

Cervical third facture - Poor prognosis if the fracture line is below alveolar crest.

Vertical fracture of root - hopeless prognosis.

Treatment

Horizontal Fracture

Stabilization to be carried out by ligation with adjacent teeth, if mobility is present.

Pulp is in a state of shock so vitality tests to be repeated after six weeks.

Apical Third Fracture

Left untreated and tooth kept under observation.

Middle Third Fracture

The coronal segment is usually mobile and needs extraction. If the apical segment is long enough, then it is extruded orthodontically and root canal treatment done followed by post and core.

Cervical Third Fracture

- Re-attachment of the segment if displaced stabilization by splinting.
- If the segment is lost, post and core is done. Prognosis is favorable.
- Emergency treatment is extraction.
- In multirooted teeth, hemisection is done.

REFERRED PAIN

Causes

- Pulpo-periapical pathosis.
- Dental pain can have its origin in trigeminal neuralgia, atypical facial neuralgia, migraine, cardiac pain, TM arthrosis.
- Sinusitis may cause pain in upper molars.
- Periodontal pain is mistaken as periapical.
- Otitis media can refer pain to mandibular molars.
- Toothache on left side can be due to myocardial infarction or angina.
- Pain from lower posterior teeth can be referred to ear or back of head.

Treatment

- Depends on diagnosis.
- Treat the associated local or systemic cause.

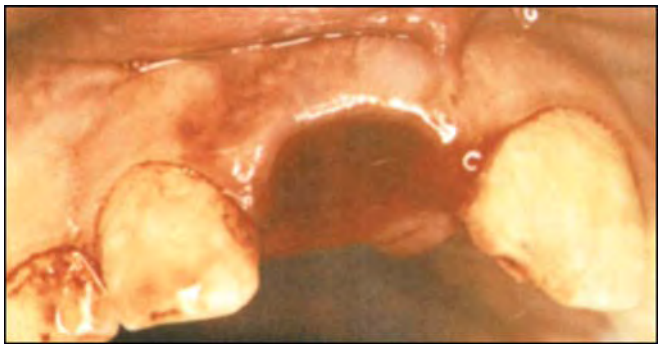


Fig. 3.9: Clinical photograph of avulsion

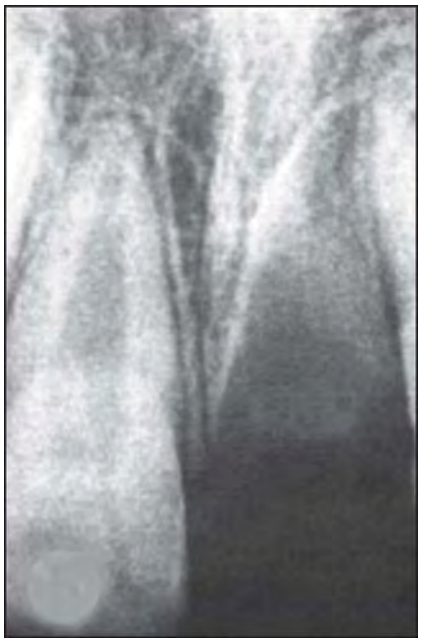


Fig. 3.10: Radiographic feature of avulsion

AVULSION (FIGS 3.9 AND 3.10)

Definition

It is defined as complete displacement of the tooth from the alveolus.

It is usually the result of trauma to an anterior tooth and is both dental and emotional problem.

Prognosis depends on the amount of time the tooth is out of the socket.

Management

- Outside the dental office.
- Success depends on the time with which the teeth are replaced.

Extraoral Time

Extraoral time should not exceed 30 minutes, should be placed within 15-20 minutes. Care should be taken not to damage the attachment apparatus.

Instructions

- Tooth should be held by the crown.
- Root is washed gently in running water or saline, and gently placed in the socket.
- Patient is brought to dental office.
- If the teeth cannot be placed in the socket.
- It should be stored in appropriate media.

Suggested Media

Vestibule of mouth, physiologic saline, milk cell culture media, Hank's balanced salt solution (HBSS).

Milk: Is considered the best medium because it has pH and osmolality compatible to vital cells and relatively free of bacteria and is readily available.

It maintains vitality of periodontal tissues for 3 hours.

Water: Tooth should not be kept in water since it is a hypotonic environment and leads to rapid cell lysis.

Management at the office (Fig. 3.11):

- If the tooth was replanted, positioning in the socket is assessed and radiograph is taken for confirmation.

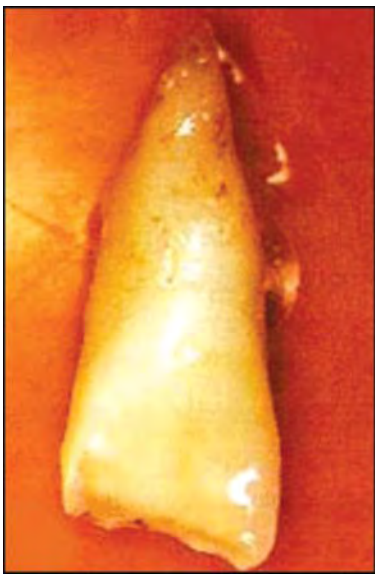


Fig. 3.11: Avulsion

- If unacceptable, tooth is removed gently and replanted.
- Splinting and soft tissue management is done.

Preparation of Root

- If extraoral time is less than 20 mins, periodontal healing is excellent.
- Root is rinsed of debris with water or saline and replanted gently.
- Prognosis depends on whether root is open or closed.
- If extraoral time is more than 60 mins. Periodontal cells have died, then the tooth is soaked in citric acid for 5 mins, in 2 percent SnF for 5 mins to remove remaining periodontal cells and replanted.
- If tooth is dry for more than 60 mins, endodontic treatment is performed extraorally. The socket is lightly aspirated if blood clot is present.

Splinting: to be done for 7-10 days (Fig. 3.12).

- The splint should allow physiologic tooth movement during healing to prevent ankylosis.
- After splinting, traumatic occlusion is avoided.
- After 7-10 days splint is removed, since 1 week is sufficient to create periodontal support.
- In case of alveolar fracture, splint is placed for 4-8 weeks.
- Management of soft tissues is done.

ADJUNCTIVE THERAPY

- Analgesics and antibiotics to prevent infection.
- chlorhexidine rinse.
- Endodontic treatment is initiated if the tooth is nonvital.

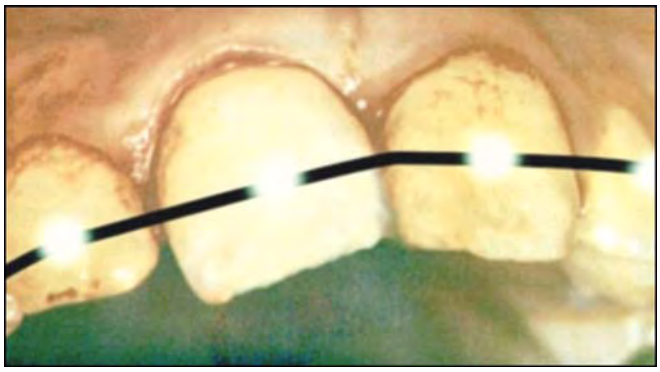


Fig. 3.12: Splinting of avulsed tooth

- In cases of open apex apexification is done.
- Follow-up care to be done every 6 months for 5 years.

Prognosis

- The failure of replantations is related to resorption
- The extraoral time is very crucial and affects the treatment results
- When teeth were replanted within 30 mins only 10 percent showed resorption whereas 95 percent resorbed when replanted more than 2 hours post trauma

ENDODONTIC FLARE UPS OR MID TREATMENT EMERGENCIES

Definition

It is defined as an acute exacerbation of periradicular pathosis after the initiation or continuation of root canal treatment.

Causes

- Inadequate debridement (residual pulp tissue)
- Debris extrusion during canal preparation. The necrotic tissue, micro-organisms, dentin filings, pulp tissue fragments may extrude periapically.
- Over instrumentation may induce inflammatory response apically
- Inadequate sterilization.
- Irrigating solutions and intracanal medicaments extruding periapically
- Over filling – extrusion of sealer or GP or both
- ZnOE sealer may induce chronic inflammation
- Untraced root canal
- Re-treatment cases have higher incidence due to associate periapical pathosis
- Associated with peri-apical lesion.
- Host factors—post operative pain depends on intensity of preoperative pain and patient apprehension.

Treatment

- Patient should be relaxed during the Rx.
- Usually postoperative pain decreases within 72 hours.
- Flare ups can be reduced by complete cleaning and shaping during initial visit.

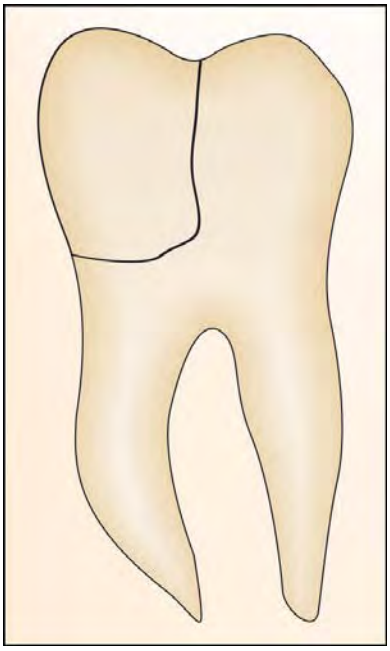


Fig. 3.13: Vertical fracture of the crown

- Calcium hydroxide dressing to prevent or treat flare ups.
- Occlusal reduction
- If necessary antibiotics and analgesics.

POST-ENDODONTIC EMERGENCIES

Fracture of the Crown (Fig. 3.13)

Vertical fracture of the crown is most commonly seen in the posterior teeth.

Causes

1. Excessive removal of natural tooth.
2. If the crown is not given in time.

Prevention

1. Care should be taken during endodontic treatment not to remove excess tooth material.
2. Following endodontic treatment the tooth should be restored either with full crown or a cast restoration as soon as possible.

Over Obturation/Under Obturation

In such cases if the patient presents with symptoms,the obturating material should be removed and reobturation should beconsidered.

SUGGESTED READING

1. A prospective randomized trial on efficacy of antibiotic prophylaxis in asymptomatic teeth with pulpal necrosis and associated periapical pathosis. Oral Surg Oral Med Oral Pathol 1988;66(6):722-33.
2. Baumgartner JC, Mader CL. A scanning electron microscopic evaluation of four root canal irrigation systems. J Endod 1987;13:147-57.
3. Berutti E, Marini R. A scanning electron microscopic evaluation of the debridement capability of sodium hypochlorite at different temperatures. J Endod 1996;22: 467-70.
4. Caliskan MK, Sen BH, Ozinel MA. Treatment of extraoral sinus tracts from traumatized teeth with apical periodontitis. Endod Dent Traumatol 1995;11(3):115-20.
5. Cooper SA. Five studies on ibuprofen for postsurgical dental pain. Am J Med 1984; 77(1A):70-77.
6. Cumming CG, Ross PW, Smith GF, Lough H, Moyes A. The use of cefadroxil in the treatment of acute orofacial infections. J Dent 1984;12(3):247-51.
7. Davis WM, Balcom JH 3rd. Lincomycin studies of drug absorption and efficacy. An evaluation by double-blind technique in treatment of odontogenic infections. Oral Surg Oral Med Oral Pathol 1969;27(5):688-96.
8. Dummer PH, Hicks R, Huws D. Clinical signs and symptoms in pulp disease. Int Endod J 1980;13:27-35.
9. Drinnan DL. Differential diagnosis of orofacial pain. Dent Clin North Am 1987;31:627-43.
10. Elliott JA, Holcomb JB. Evaluation of a minimally traumatic alveolar trephination procedure to avoid pain. J Endod 1988;14(8):405-07.
11. Fazakerley MW, McGowan P, Hardy P, Martin MV. A comparative study of cephradine, amoxycillin and phenoxymethylpenicillin in the treatment of acute dentoalveolar infection. Br Dent J 1993;174(10):359-63.
12. Franklin A, Calver RF. Packing of abscess cavities. Lancet 1973;2(7828):573-74.
13. Garfunkel A, Sela J, Ulmansky M. Dental pulp pathosis; clinico-pathological correlations based on 109 cases. Oral Surg 1973;35:110-17.
14. Gill Y, Scully C. The microbiology and management of acute dentoalveolar abscess: views of British oral and maxillofacial surgeons. Br J Oral Maxillofac Surg 1988; 26(6):452-57.
15. Hasler JF, Mitchell DF. Analysis if 1628 cases of odontalgia: A corroborative study. J Indianapolis District Dent Soc 1963;17:23-25.
16. Harrington GW, Natkin E. Midtreatment flare-ups. Dent Clin North Am 1992;36:409-23.
17. Habib S, Matthews RW, Scully C, Levers BG, Shepherd JP. A study of the comparative efficacy of four common analgesics in the control of postsurgical dental pain. Oral Surg Oral Med Oral Pathol 1990;70(5):559-63.
18. Jackson DL, Moore PA, Hargreaves KM. Preoperative nonsteroidal antiinflammatory medication for the prevention of postoperative dental pain. J Am Dent Assoc 1989;119(5):641-47.

19. Kandemir S, Ergul N. Grievances in cases using antibiotics due to orodental problems and assessment of the need for antibiotics. Int Dent J 2000;50(2):73-77.
20. Krishnan V, Johnson JV, Helfrick JF. Management of maxillofacial infections: a review of 50 cases. J Oral Maxillofac Surg 1993; 51(8):868-73; discussion 873-74.
21. Legg JA, Wilson M. The prevalence of beta-lactamase producing bacteria in subgingival plaque and their sensitivity to Augmentin. Br J Oral Maxillofac Surg 1990; 28(3):180-84.
22. Longman LP, Preston AJ, Martin MV, Wilson NH. Endodontics in the adult patient: the role of antibiotics. J Dent 2000;28:539-48. Abbott AA, Koren LZ, Morse DR, Sinai IH, Doo RS, Furst ML.
23. Mosaku AO, Watkins KEE, Grey NJA. The hot water test: a diagnostic procedure and a case report. CPD Dentistry 2000;1:101-03.
24. Marshall JG, Liesinger AW. Factors associated with endodontic posttreatment pain. J Endod 1993; 19(11):573-75.
25. Mehlisch DR, Sollecito WA, Helfrick JF, Leibold DG, Markowitz R, Schow CE Jr, et al. Multicenter clinical trial of ibuprofen and acetaminophen in the treatment of postoperative dental pain. J Am Dent Assoc 1990; 121(2):257-63.
26. Menke ER, Jackson CR, Bagby MD, Tracy TS. The effectiveness of prophylactic etodolac on postendodontic pain. J Endod 2000; 26(12):712-15.
27. Morse DR, Furst ML, Belott RM, Lefkowitz RD, Spritzer IB, Sideman BH. Infectious flare-ups and serious sequelae following endodontic treatment: a prospective randomized trial on efficacy of antibiotic prophylaxis in cases of asymptomatic pulpal-periapical lesions. Oral Surg Oral Med Oral Pathol 1987;64(1):96-109.
28. Nakamura Y, Hirayama K, Hossain M, Matsumoto K. A case of an odontogenic cutaneous sinus tract. Int Endod J 1999;32(4):328-31.
29. Novaes Junior AB, Novaes AB. Immediate implants placed into infected sites: a clinical report. Int J Oral Maxillofac Implants 1995;10(5):609-13.
30. Pais JM, Rosteiro FM. Nimesulide in the short-term treatment of inflammatory process of dental tissues: a double-blind controlled trial against oxyphenbutazone. J Int Med Res 1983;11(3):149-54.
31. Seltzer S, Bender IB, Zionitz M. The dynamics of pulp inflammation: Correlation between diagnostic data and histologic findings in the pulp. Oral Surg 1963;16: 846-71, 969-77.
32. Schuen NJ, Panzer JD, Atkinson WH. A comparison of clindamycin and penicillin V in the treatment of oral infections. J Oral Surg 1974;32(7):503-05.
33. Shelley JJ, Shipman GL, Hecht RC. Adverse reaction to ibuprofen overdose. Gen Dent 1994;42(5):414-16.
34. Torabinejad M, Cymerman JJ, Frankson M, Lemon RR, Maggio JD, Schilder H. Effectiveness of various medications on postoperative pain following complete instrumentation. J Endod 1994;20(7):345-54.
35. Von Konow L, Nord CE. Ornidazole compared to phenoxymethyl penicillin in the treatment of orofacial infections. J Antimicrob Chemother 1983;11(3):207-15.
36. Walton RE, Chiappinelli J. Prophylactic penicillin: effect on posttreatment symptoms following root canal treatment of asymptomatic periapical pathosis. J Endod 1993;19(9):466-70.
37. Woods R. Diagnosis and antibiotic treatment of alveolar infections in dentistry. Int Dent J 1981;31(2):145-51.
38. Watts A, Patterson RC. The response of the mechanically exposed pulp to prednisolone and triamcinolone acetonide. Int Endod J 1988;21:9-16.

Rationale of Endodontic Treatment 4

Inflammation is the most common and most important of all disease process. We all have suffered from minor injuries to major multiple diseases and from trauma to infection. Inflammation is principle safe guard against any type of injury or infection. If there is impairment in the inflammatory process, it will lead to serious consequences to the human body.

Definition

Inflammation is local reaction of the living tissue to injury (Fig. 4.1).

This definition is exactly not correct. For example, in case of cancer, first it will affect localized area in body, but gradually it will spread all the tissues in human being. So the definition emphasizes first the local reaction where vascular dilatation and escapes of cells from blood occurs.

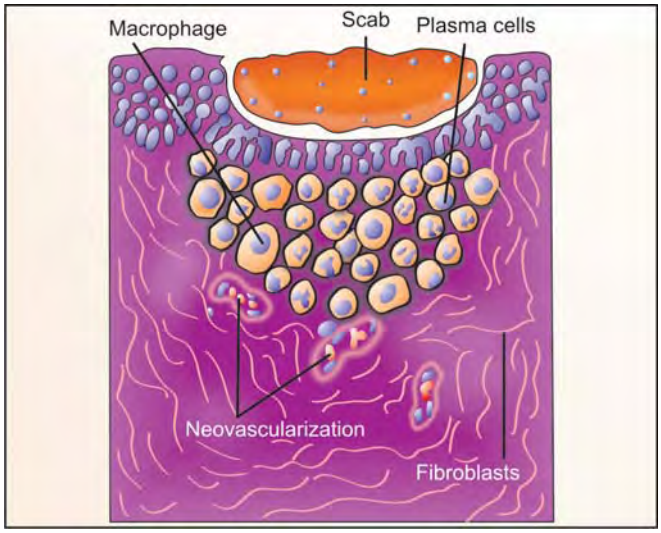


Fig. 4.1: Inflammatory cells at a healing site

In long term, it will change/affect the most tissues whichever is necessary.

Causes for Inflammation

1. Trauma
2. Bacteria
3. Fungi
4. Virus
5. Parasite
6. Radiation
7. Poison
8. Metabolic disorder
9. Derangement of immune system.

Signs and Symptoms

There are five signs and symptoms during inflammation.

1. *Pain:* Due to the release of toxins from the bacteria, hormones and cellular elements at nerve tissue.
2. *Swelling:* It is due to infiltration of cells and fluid from blood vessels.
3. & 4. *Redness and heat:* Due to the vasodilatation of vessels
5. *Disturbance of function:* Due to above changes of the affected tissue, which is unable to do normal function.

Types of Inflammation

There are four types of inflammation.

1. *Acute inflammation:* It develops quickly within minutes of injury. It lasts within few days/weeks. Microscopic examination shows dilated blood

vessels at inflamed tissue with some edema. The most important feature is presence of neutrophils.

2. *Chronic inflammation:* It is a longer duration, due to the inflammation in the body. All the infected symptoms gradually subside, only very few WBC are present. Most common are lymphocytes, plasma cells, monocytes and macrophages.
3. *Subacute inflammation:* It is mixed type, difficult to judge. Under microscope, there are mixed cells, with very few neutrophils and most monocytes and lymphocytes.
4. *Granulomatous inflammation:* In this type encapsulation seen with collagen tissue, inflammatory exudate and cells.

Inflammatory procedure can be divided into two phases:

- According to Boyd, vascular change occurs before cellular changes.
- According to Grossman, cellular changes occur first and then vascular changes.

Cellular Changes (Figs 4.2 and 4.3)

1. Neutrophils
2. Macrophages
3. Lymphocytes
4. Eosinophils, basophils and mast cells.

1. *Neutrophils (Fig. 4.4):* It contains single nucleus with multiple lobules. The functions of neutrophils are:
   a. Phagocytosis
   b. Fibrinolysis

   Removal of cellular debris: There is an alteration in the area by chemotactic factors produced by bacteria or complement. The bacteria binds to surface of neutrophil by a substance called opsonins which are produced by immunoglobulin factor.

   They engulf the bacteria and liberate the enzymes to lyses of bacteria. The life of these cells has a narrow range. Below pH of 6.5, they will not survive due to production of lactic acid. They also release proteolytic enzymes such as pepsin and cathepsin.
2. *Macrophages (Fig. 4.5):* It is mononucleated cell. They may fuse with other macrophages and becomes multinucleated giant cell. They enhance immunoglobulin reaction. It has capacity to remove debris and to facilitate repair.
3. *Lymphocytes (Fig. 4.6):* These are intimately related to immunoglobulin system of the organism. It has

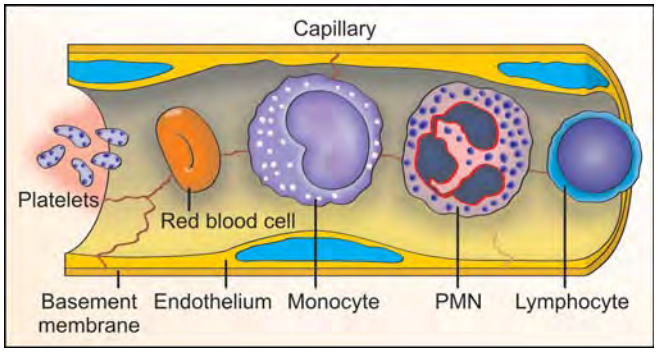


Fig. 4.2: Schematic cross-section of a capillary showing various blood cells

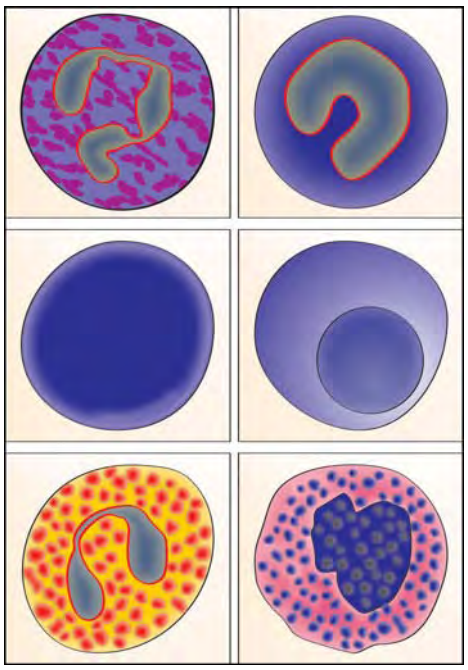


Fig. 4.3: White blood cells

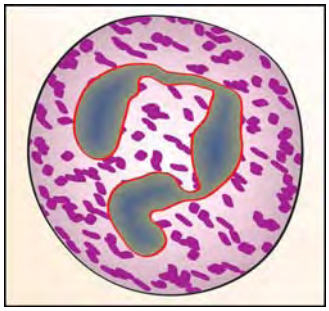


Fig. 4.4: Neutrophil

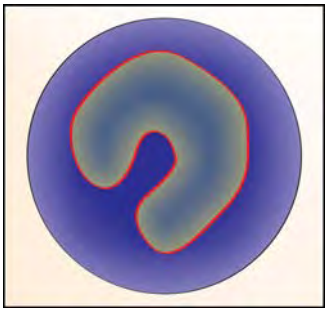


Fig. 4.5: Macrophage

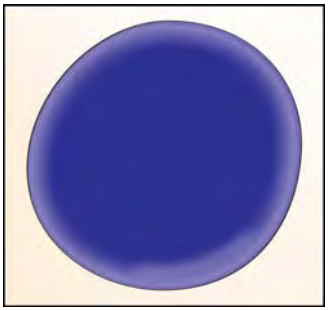


Fig. 4.6: Lymphocyte

larger nucleus with slight cytoplasm containing granules. These are two types T cells and B cells.

T Cells have longer life span and more active for immulogical reaction.

B Cells have lesser short life than T cells and lesser in number in blood circulation. These are stored in lymphatic tissue.

The immunoglobulins are divided into 5 groups: IgA, IgM, IgE, IgD, and IgG.

The functions of these five groups are:

a. Neutralization of bacterial toxins.
b. Coating of bacteria with antibody such as opsonins.
c. Lysis of bacteria.
d. Agglutination of bacteria.
e. Combine with antibodies with virus to prevent entry in human organs.

4. *Eosinophils (Fig. 4.7):* These are commonly seen allergic and parasitic conditions.

Basophils and mast cells

Basophils and mast cells produce histamine and heparin. The function of histamine is to produce vasodilation and heparin acts as anticoagulant.

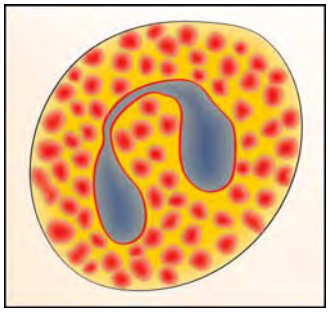


Fig. 4.7: Eosinophil

Inflammatory mediators and their secretion

Chemotactic factors	
Bacterial products	Neutrophils Macrophages
Complement	Neutrophils Macrophages
C3	
C5a	
C5b67	
Ba	
large fragment of C5	Fibrocytes
large fragment of C5	Tumor cells
Lymphokines	Neutrophils Macrophages Eosinophils Basophils Lymphocytes Fibrocytes
Mast cells	
Eosinophil cheotactic factor of anaphylaxis	
High molecular wight substance	
Low molecular weight substance	
Histamine	
Other	
Kallikrein	
Kinins	
Prostaglandin E	
Thromboxane B_2	
Neutrophil secretions	
Monokines	
Fibrin breakdown products	
N-formylmethionyl peptides	
Leukotriene B4	

Vascular Changes (Figs 4.8 to 4.12)

Initially there is brief vasoconstriction and followed by vasodilatation. In vasodilatation, arterioles dilate by relaxation of arteriolar and capillary sphincters. Due to this, opening of capillary bed to increase blood

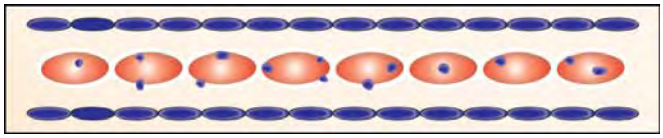


Fig. 4.8: Normal blood vessel

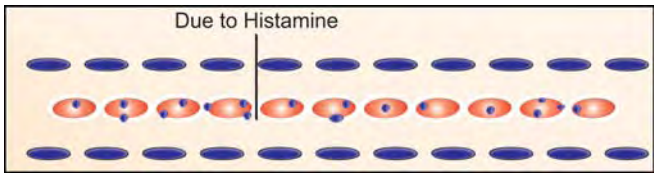


Fig. 4.9: Due to Histamine

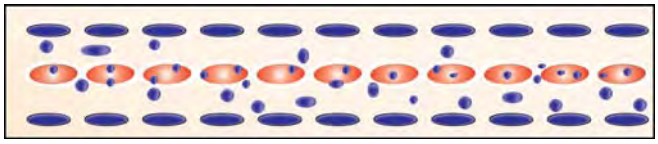


Fig. 4.10: Margination

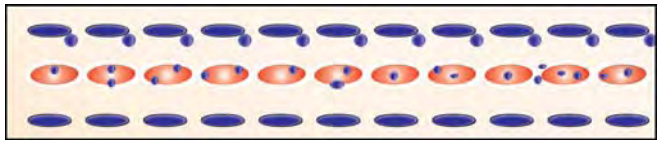


Fig. 4.11: Pavementing

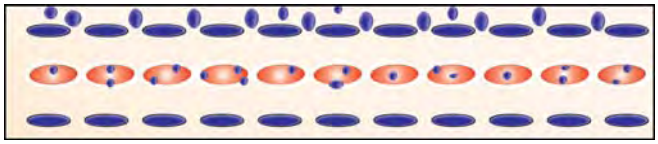


Fig. 4.12: Emigration

flow at affected areas. This is due to release of proteolytic enzymes, bacterial toxins and histamine. Vasodilation is increased, thus decreasing blood flow leading to increases intravascular pressure.

Meanwhile histamine enhances the permeability of blood vessels by constriction of epithelial cells at blood vessels.

So blood plasma escapes through the blood vessels which is less viscous and contains less protein, comparing the blood remaining in the vessels. The proteins normally present are albumin, fibrinogen and immunoglobulin. Meanwhile the blood in the vessels becomes slow down. Normally, cells travel in the center of flow. When blood flow slows down, cells move towards the periphery. The leukocytes move from the center to the periphery is called margination. Slowly the leukocytes attached to the walls, it is called pavementation. The step emigration means coming out from the blood vessels. This migration process is called chemotaxis.

Hageman factor or factor XII of the blood clotting system is released. The function of Hagemen factor is to activate fibrinogen into fibrin, which confines exudates at inflammation site. Now this whole process is to facilitate migration of leukocyte to inflammatory area to defend against bacteria.

Periradicular Manifestations

Due to the presence of bacteria and toxins pulp may become partially or completely necrotic. It serves the pathway to the periradicular area, which contains necrotic material, antigen and antibodies. These products are responsible for bone resorption and granulation tissue in place of normal periradicular tissue. Tissue changes following inflammation are regenerative changes and proliferative changes.

Factors causing increased permeability	
Amines	
	Histamine
	Serotonin
Kinins	
	Bradykinin
	Kallidin II
	Hendecapeptide
Complememnt	
	C3a
	C5a
	C4a
	Fragments of C2
Prostaglandins	
	Prostaglandin E
	Prostacyclin
Leukotrienes	
Leukotrienes C4, D4, E4	
Other	
	Acidity
	Adenosine
	Adenylic acid
	Fibrin breakdown products
	Free radicals
	Lymphokines
	Platelet activating factor

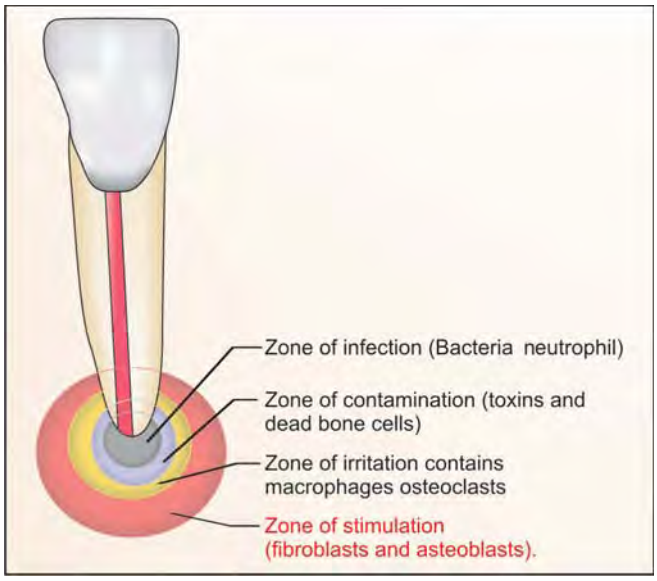


Fig. 4.13: Zones of Fish

Endodontic Implications (Fig. 4.13)

The reaction of periradicular tissue to bacterial toxins, necrotic tissue and antigen agents was studied by Fish. Fish drilled a hole on the jaws of guinea pigs and kept foci of infection in that hole. He discussed four well-defined zones of reaction depending upon the concentration of foci or toxins.

1. Zone of infection.
2. Zone of contamination.
3. Zone of irritation.
4. Zone of stimulation.

These zones are formed due to the dilution of toxin towards bone.

Now question arises why so much importance is given to rationale endodontic treatment. The answer is very simple. Root canal is opened so as to reduce bacteria and toxins at the apex to enhance repair.

CONCLUSION

By removing or reducing bacteria and toxins in the root canal, it can be obturated without any periapical inflammatory process. But it is a fact that bacteria are not mobile in the root canal, but it can multiply and liberate toxins. So it is very important to understand inflammation and rationale endodontic treatment to preserve the natural tooth in oral cavity.

SUGGESTED READING

1. Bhaskar SN. Orban's oral histology and embryology. 9th ed. St. Louis; CV Mosby; 1980.
2. Brännström M, Astrom A. The hydrodynamics of the dentin: its possible relationship to dentinal pain. Int Dent J 1972;22:219.
3. Bei M, Maas R. FGFs and BMP4 induce both Msx1-independent and Msx1-dependent signaling pathways in early tooth development. Development 1998;125:4325.
4. Brännström M. Dentin and pulp in restorative dentistry. 1st ed. Nacka (Sweden): Dental Therapeutics AB; 1981.
5. Chen Y, Bei M, Woo I, et al. Msx1 controls inductive signaling in mammalian tooth morphogenesis. Development 1996;122:3035.
6. Dippel HW, et al. Morphology and permeability of the dentinal smear layer. J Prosthet Dent 1984;52:657.
7. Goldman LB, Goldman M, Kronman JH, Lin PS. The efficacy of several irrigating solutions for endodontics: a scanning electron microscopic study. Oral Surg 1981;52:197.
8. Johnson G, Brännström M. The sensivity of dentin: changes in relation to conditions at exposed tubules apertures. Acta Odontol Scand 1974;32:29.
9. Lumsden AGS. Neural crest contribution to tooth development in the mammalian embryo. In: Maderson PFA, (Ed): Developmental and Evolutionary Aspects of the Neural Crest. New York: John Wiley and Sons; 1988; 261.
10. MacNeil RI, Thomas HF. Development of the murine periodontium. I. Role of basement membrane in formation of a mineralized tissue on the developing root dentin surface. J Periodontol 1993;64:95.
11. MacNeil RI, Thomas HF. Development of the murine periodontium. II. Role of the epithelial root sheath in formation of the periodontal ligament. J Periodontol 1993;64:285.
12. Meyer M, et al. Blood flow in the dental pulp. Proc Soc Exp Biol Med 1964;116:1038.
13. Michelich VJ, Schuster GS, Pashley DH. Bacterial penetration of human dentin, in vitro. J Dent Res 1980;59:1398.
14. Neubuser A, Peters H, Balling R, Martin GR. Antagonistic interactions between FGF and BMP signaling pathways: amechanism for positioning the sites of tooth formation. Cell 1997;90:247.
15. Ogilvie RW, et al. Physiologic evidence for the presence of vasoconstrictor fibers in the dental pulp. J Dent Res 1966;45:980.
16. Olgart L, Brännström M, Johnson G. Invasion of bacteria into dentinal tubules. Experiments in vivo and in vitro. Acta Odontol Scand 1974;32:61.
17. Pashley DH, Michelich V, Kehl T. Dentin permeability: effects of smear layer removal. J Prosthet Dent 1981;46:531.
18. Pashley DH, Livingston MJ, Reeder OW, Horner J. Effects of the degree of tubule occlusion on the permeability of human dentin, in vitro. Arch Oral Biol 1978; 23:1127.

19. Pashley DH, Tao L, Boyd L, et al. Scanning electron microscopy of the substructure of smear layers in human dentine. Arch Oral Biol 1988;33:265.
20. Pashley DH. The smear layer: physiological considerations. Oper Dent 1984; Suppl 3:13.
21. Pashley DH, Galloway SE, Stewart FP. Effects of fibrinogen in vivo on dentine permeability in the dog. Arch Oral Biol 1984; 29:725.
22. Slavkin HC. The nature and nurture of epithelial-mesenchymal interactions during tooth morphogenesis. J Biol Buccale 1978;6:189.
23. Slavkin HC, Chai Y, Hu CC, et al. Intrinsic molecular determinants of tooth development from specification to root formation: a review. In: Davidovitch Z, (Ed). The Biological Mechanisms of Tooth Eruption, Resorption and Replacement by Implants. Birmingham (AL): EBSCO Media; 1994; p. 263.
24. Slavkin HC, Diekwisch T. Evolution in tooth developmental biology of morphology and molecules. Anat Rec 1996;245:131.
25. Thesleff I. The teeth. In: Thorogood P (ed). Embryos, genes and birth defects.New York: John Wiley and Sons; 1997; 329.
26. Tucker AS, Matthews KL, Sharpe PT. Transformation of tooth type induced by inhibition of BMP signaling. Science 1998;282:1136.
27. Wisniewski K, et al. The effects of products of fibrinogen digestion by plasmin (P-FDP) on the central nervous system. Acta Neurobiol Exp 1975;35:275.

BASIC MICROBIOLOGY

Introduction

Oral cavity is a sea of microorganisms. These microorganisms play a very important role in the human ecosystem. The microorganisms most of the times are harmless, but in some cases specially when they get proper nutrition or the host defense is low, these can increase in number to such an extent that they are capable of causing immense harm to the host. So here is a brief discussion about the various microorganisms present in the oral cavity and their significance.

History

1st BC - Varo and Columella postulated that diseases were caused by invisible beings.

1683 - Antony von Leeuwenhoek first observed microorganisms and called them "little animalcules".

1822 - 95 - Louis Pasteur

1843 - 1910 - Robert Koch

} Discovered role of microorganisms in etiology of disease

1827 - 1912 - Joseph Lister proposed that post operative infections occurred due to microbes in air and stressed upon the importance of asepsis.

1890 - WD Miller studied microorganisms of human mouth and proposed that bacterial fermentation of sugar caused caries.

1936 - Fish and Mc Lean said that pulps of healthy vital teeth were sterile.

1976 - Sundquist gave the role of anaerobic bacteria in endodontic infections.

1999 - Baumgartner observed that predominant anaerobes in endodontic infections were *P. nigrescens* and *P. intermedia*.

Classification of Microorganisms

A. Based on presence or absence of nucleus

Prokaryotes	*Eukaryotes*
• Ex-Bacteria	• Ex-Fungi, protozoa, algae, etc.
• Nucleolus and nuclear membrane absent	• Nucleolus and nuclear membrane present
• Single chromosome	• Multiple chromosomes
• Membrane bound organelles absent	• Membrane bound organelles present (mitochondria, ER, Golgi)
• Ribosomes - 70s	• Ribosomes - 80s
• Respiration by cell membrane	• Respiration by mitochondria

B. Microorganisms can be broadly classified into:

1. Bacteria
2. Viruses
3. Fungi
4. Mycoplasma
5. Rickettsia
6. Chlamydia

STRUCTURE OF BACTERIA (FIG. 5.1)

Bacteria have an outer cell envelope consisting of a rigid cell wall which accounts for the shape of the cell.

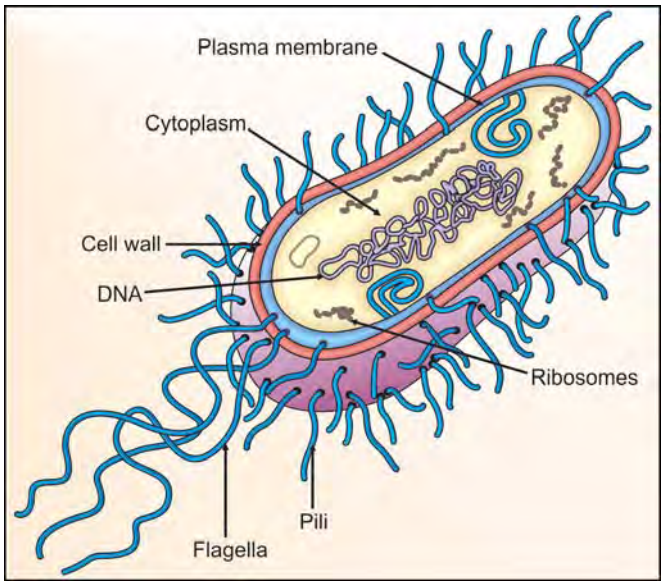


Fig. 5.1: Structure of bacteria

The cell wall is about 10-25 nm in thickness. This cell wall has the bacterial antigens responsible for the virulence and immunity of the organism.

The inner cytoplasmic membrane is a thin layer of 5 - 10 nm thickness which lines the cell from inside. It is semipermeable in nature and allows passage of nutrients and metabolites to and from the cell.

The cytoplasm of bacteria is devoid of organelles like endoplasmic reticulum. But it contains ribosomes, mesosomes, and vacuoles. The ribosomes are the centers for protein synthesis. The mesosomes are vesicular, convoluted structures present as invaginations of plasma membrane. They are principal sites of respiratory enzymes in bacteria and are analogous of mitochondria in eukaryotes.

Bacterial nuclei have no nuclear membrane or nucleolus. Genome consists of single molecule of double stranded DNA arranged in the form of a circle. Bacteria may also possess certain extranuclear genetic material called plasmids or episomes which contribute to properties like toxigenicity and drug resistance.

Some bacteria secrete a viscid material around its surface. When this is well organized with a defined structure, it is called the capsule. If it is not well organized, then it is called slime layer. This capsular material is antigenic in nature and can be demonstrated by various serological methods. Capsules protect bacteria from deleterious agents like lytic enzymes and also contribute to the virulence of organism by inhibiting phagocytosis.

Motile bacteria have one or more long filaments called flagella which are the organs of locomotion. They consist of 3 parts—the filament, body and the hook. Flagella are about 0.02 µ in thickness.

Some gram-negative organisms have very fine hair like appendages called pili or fimbriae. They are shorter and thinner than the flagella. These act as organs of adhesion helping the cells to adhere firmly to various particles. These are also antigenic in nature. The sex pili are longer and fewer in number and are present on male bacteria and help in their attachment to female bacteria through which genetic material is transferred.

Some bacteria have the ability to form highly resistant resting stages called spores. These are the most resistant forms of life and can survive up to several centuries in the unsuitable environment. They are highly resistant to desiccation, chemicals and heat. In presence of conditions conducive to vegetative growth, they germinate.

Bacteria can be classified based on their shape into (Fig. 5.2):

Cocci	–	Spherical / oval cells
Bacilli	–	Rod shaped cells
Vibrio	–	Comma shaped cells (vibratory motility)
Spirilla	–	Rigid spiral forms
Spirochetes	–	Flexuous spiral forms

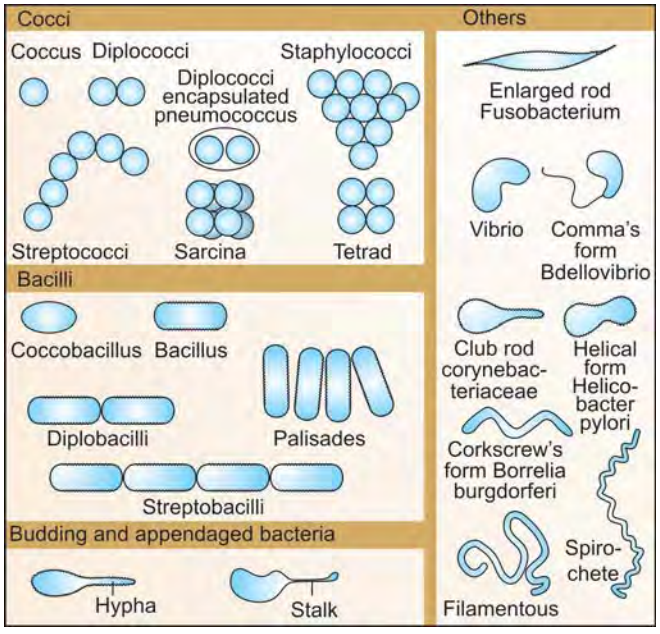
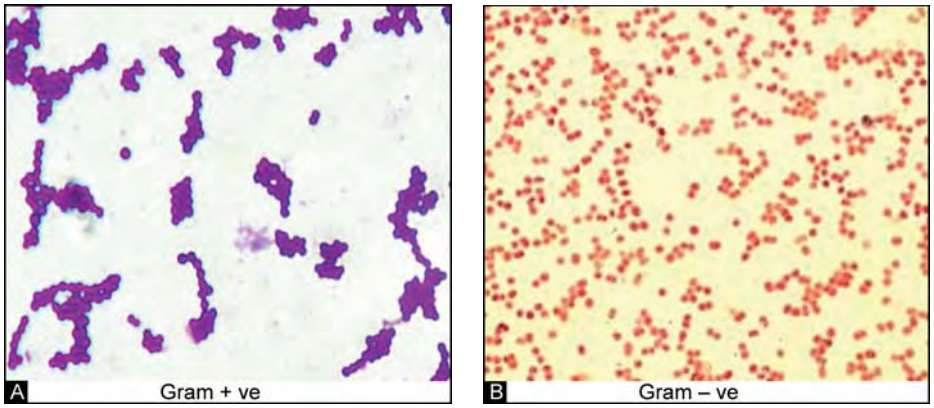


Fig. 5.2: Morphology of bacteria



Figs 5.3A and B: (A) Gram + ve (B) Gram - ve

Actinomycetes – Branching filamentous form (sun ray pattern)
Mycoplasma – No stable morphology
Pleomorphic – Varying shapes (deficient cell wall)

Based on kind of flagella:

- Atrichous
- Monotrichous
- Lophotrichous
- Amphitrichous
- Peritrichous

Based on Gram staining (Figs 5.3A and B)

First introduced by Christian Gram in 1884 and is done in 4 steps:

- Primary staining with crystal violet, gentian violet
- Application of dilute solution of iodine
- Decolorization with organic solvent like ethanol
- Counter stain with carbol fuschin

- Gram +ve - resist decolorization and retain original stain
- Gram -ve - get decolorized and take up the counter stain

This difference in both type of organisms is due to difference in permeability of bacterial cell wall and cytoplasmic membrane to dye iodine complex.

Based on arrangement of cells:

In pairs – Diplococci'
In chains – Streptococci
In fours – Tetrad
In eights – Sarcina
In clusters – Staphylococci

Based on physiologic characteristics (ideal growth environment):

i. Obligate aerobies:
a. Require O_2 to grow
b. Possess catalase and superoxide dismutase, e.g. *Mycobacterium tuberculosis*

ii. Facultative anaerobes:
a. Grow in presence or absence of O_2
b. Possess catalase and superoxide dismutase, e.g . *Streptococcus mutans*

iii. Microaerophilic:
a. Grow in areas with less O_2 tension
b. Contain superoxide dismutase
c. Do not possess catalase, e.g. *Campylobacter*

iv. Obligate anaerobes:
a. Grow in absence of O_2
b. Lack superoxide dismutase and catalase.

Based on size of organism

Normally, size of bacteria - 1.5 µ wide and 2 - 6 µ long
Smallest - Mycoplasma (0.1 µ)
Largest - Beggiatoa (26 - 60 µ)

STRUCTURE OF A VIRUS (FIG. 5.4)

Virus is the smallest living unit on earth and present as the twilight zone between the living and the non-living. These are ultramicroscopic in nature and are smaller than bacteria. The extracellular infectious particle is called a virion.

They essentially consist of a nucleic acid core surrounded by a protein coat called the capsid. The capsid along with the nucleic acid is called the nucleocapsid. This protects the nucleic acid from

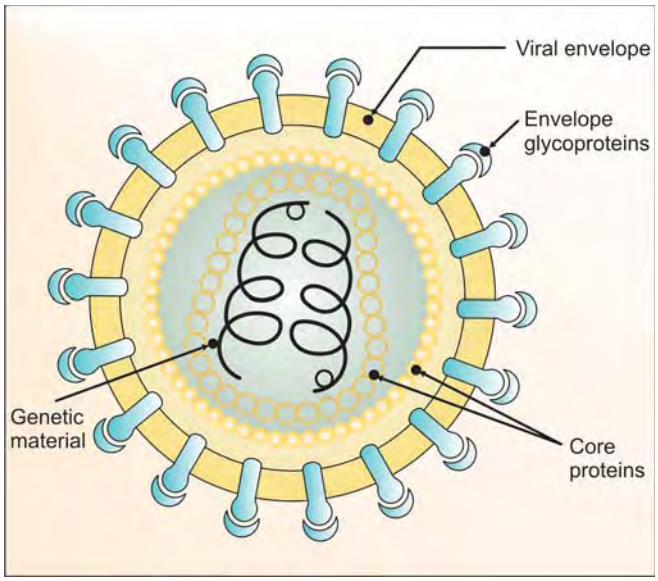


Fig. 5.4: Structure of a virus

inactivation by nucleases and other deleterious agents. The capsid is made up of many capsomers. One of the major functions of capsid is to introduce viral genome into host cell by adsorbing onto the cell surfaces.

The virions may be enveloped which is made up of lipoprotein. These contribute to the chemical, antigenic and biological properties of virus. The enveloped viruses are susceptible to action of lipid solvents like ether and chloroform.

Viruses contain only one type of nucleic acid either single or double stranded RNA or DNA.

STRUCTURE OF FUNGI

Fungi are eukaryotic protista. They have a rigid cell wall containing chitin, mannan and other polysaccharides. The cytoplasmic membrane contains sterols. These contain true nucleus with a nuclear membrane and paired chromosomes. They divide asexually, sexually or by both processes. They may be unicellular or multicellular.

Depending upon the cell morphology, they can be divided into (Fig. 5.5):

Yeasts – Unicellular fungi which occur as spherical or ellipsoidal cells. Reproduce by simple budding. Ex - *Cryptococcus neoformans*.

Yeast like fungi – Grow partly as yeast and partly as elongated cells resembling hyphae which form pseudomycelium. Ex- *Candida albicans*.

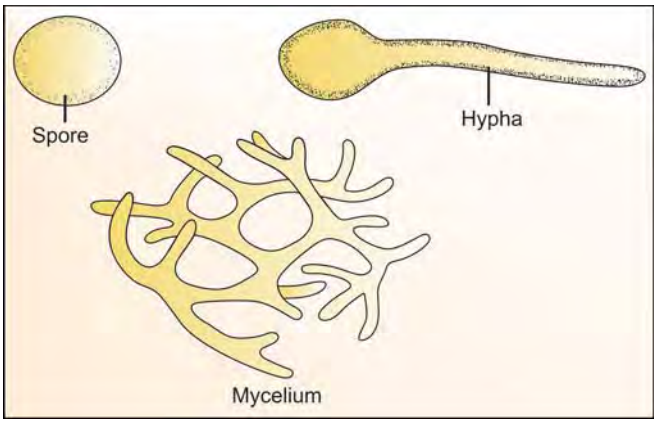


Fig. 5.5: Fungal morphology

Moulds – These form true mycelia and reproduce by formation of different types of spores. Ex - Dermatophytes.

Dimorphic fungi – These occur as filaments or as yeasts depending on conditions of growth. In host tissues or cultures at 37°C, they occur as yeasts. In soil and cultures at 22°C, occur as moulds. These are responsible for most of the systemic infections.

BIOFILM

A biofilm is a complex aggregation of microorganisms marked by the excretion of a protective and adhesive matrix. Biofilms are also often characterized by surface attachment, structural heterogeneity, genetic diversity, complex community interactions, and an extracellular matrix of polymeric substances.

Biofilm is the form in which bacteria lives as a community. It acts as protective environment for microorganisms. This ecosystem renders the microbial complex 500 times more resistant to antimicrobial agent than the free floating bacteria. It also acts as reservoir for accumulating and concentrating nutrients required for the survival of microorganisms.

The concept of biofilms was not recognized until 1978. It took almost two decades until it was accepted scientifically by the clinicians. The subject came to highlight in July 1996 by Nobel laureate "Joshua Lederburg in the conference called "Microbial ecology and Infectious disease" hosted by national institute of dental research in the Bethesda. After two months

American society of microbiology hosted a conference on biofilm at Utah. These conferences further placed the clinical relevance and significance of biofilms in the forefront.

Advances in the scientific research instruments such as confocal microscopy, atomic force, tunnel microscopy, assisted with digital imaging technology aided in detection, detailed description and composition of biofilms. The biofilms can act by preventing the following defense mechanisms:

a. Alteration in the host immune response, which is rendered ineffective, and cannot remove the biofilm.
b. These co-aggregations are highly resistant to host immunoglobulins, antibiotics and antifungal treatments.

Stages of Biofilm Formation

Single-celled organisms generally exhibit two distinct modes of behavior. The first is the free floating, or planktonic, form in which single cells float or swim independently in some liquid medium. The second is an attached state in which cells are closely packed and firmly attached to each other and usually a solid surface. The change in behavior is regulated by many factors and mechanisms that vary between species. When a cell changes modes, it undergoes a phenotypic shift in behavior in which large suites of genes are up- and down- regulated.

The initial stage of biofilm formation involves the formation of a conditioning film wherein there is an adsorption of macromolecules in the planktonic phase (free floating) to the surface. The conditioning film is composed of proteins and glycoproteins from saliva and gingival crevicular fluid, and some secreted products microorganisms. This conditioning film is formed before the colonization of bacteria and selectively promotes adhesion of certain strains of bacteria. Numerous microorganisms in the planktonic phase will be transported to the surface but it is the properties of the conditioning film that determine those microorganisms, which attach, and thereby influence the microbial composition of the biofilm.

The second stage involves two steps, i.e. adhesion and coadhesion of microorganisms. This attachment is reinforced through polymer production and unfolding of cell surface structures. Commonly specific early colonizers seem to play an important role for the subsequent coadhesion of other organisms. For example, streptococcal strains are among the early colonizers on tooth surfaces and appear to provide important features for the subsequent attachment of both gram-positive and gram-negative organisms.

In the third stage, there will be multiplication and metabolism of attached microorganisms that will result in a structurally organized mixed microbial community. During this stage the inherent characteristics of the microorganisms and the nature of the environment influence growth and succession of microorganisms in the biofilm.

The rate of detachment of microorganisms from dental biofilms is not clear. Keeping in mind that the number of microorganisms in the planktonic phase (saliva) averages ten to hundred million per milliliter and that these microorganisms originate from dental and soft tissue biofilms, the detachment of microorganisms should be seen as a continuous process during development. It is known from *in vitro* studies that monolayers of oral bacteria release enzymes that mediate their detachment.

Biofilm on Root Canal Surfaces

Oral environment is the common source for microorganisms that may colonize root canal surfaces after loss of pulpal vitality; there is little formation of biofilms in endodontic infections. Study related to biofilms in infected root canals was carried out by Nair. He described it as the major bulk of the organisms existed as "loose collections" of cocci, rods, filaments and spirochetes. While most of these organisms appeared suspended, in a moist canal space, dense aggregates were also observed sticking to the canal walls and forming thin to thick layers of bacterial condensations. Amorphous material filled the inter-bacterial spaces and was interpreted as an extracellular matrix of bacterial origin. When they occurred, the bacterial condensations showed a palisade structure similar to the one for dental plaque on external tooth surfaces, suggesting similar mechanisms for bacterial attachment as those for dental plaque.

Antimicrobials and Biofilm

Resistance of biofilm communities to anti-microbials is attributed to a various mechanisms.

1. The structural organization of the biofilm species within the polymeric matrix might restrict the penetration of the agent into the biofilm leaving deeper microorganisms unaffected.
2. The agent might also be inactivated in the biofilm by bacterial products.
3. The slow growth rate of microorganisms in established biofilms can result in cells being more resistant to the agent than faster dividing cells.
4. Biofilm bacteria may also present a distinct phenotype that is responsible for the enhanced resistance.

The role of the biofilm concept to endodontics will help to understand, the pathogenicity of endodontic microflora and opens door for new approaches to infection control. More research is required regarding adapting capabilities of microorganisms under different disease conditions and how biofilms are organized in root canals. These important issues are to be addressed to have a better understanding of endodontic failures due to root canal bacteria.

ENDODONTIC MICROBIOLOGY

This deals with the microorganisms associated with pulp and periapical diseases.

In 1890, WD Miller associated the presence of bacteria to pulpal disease and stated that endodontic infections are polymicrobial in origin.

Routes of Microbial Entry to the Pulp

Microorganisms may invade the pulp by three primary routes:

- Direct access
- Pulp-periodontal pathway
- Bloodstream

Direct Access

Direct access to the pulp can be obtained by either of the two ways:

1. *Via pulp exposure:* This is the most common route of microbial infection / invasion of the pulp, which occurs due to extension of the lesion into pulp cavity. Other possible causes of pulp exposure include:
   - Excessive loss of tooth structure due to erosion, attrition or abrasion.
   - Deep cavity and crown preparation.
   - Tooth fracture due to acute trauma.
2. *Via open dentinal tubules:* Dentinal tubules usually open up during the procedure of tooth preparation or caries excavation.

Many experimental studies have indicated that microorganisms inhabit dentinal tubules but pose little or no threat to pulp, if the thickness of dentin is more than 0.5 mm.

Pulpo-periodontal Pathway

A pulpo-periodontal pathway hypothesis has been proposed on the assumption that microorganisms may invade the pulp by either of the following anatomic features:

- Via lateral canals.
- Via apical foramina

It is apparent from the pathogenesis of endodontic diseases that pulp pathosis always precedes periapical disease. Therefore, it is postulated that microorganisms and their toxic products as well as pulp degradation products gain access to the apical periodontium via apical foramina, and thereby initiate periapical disease.

A study conducted by T Kobayashi (1990, IEJ) on the association of microflora from root canals and periodontal pockets of non-vital teeth with advanced periodontitis, concluded to state that periodontal pocket may be a possible solution of root canal infections, with *Streptococcus*, *Peptostreptococcus*, *Eubacterium*, *Bacteroides* and *Fusobacterium*, as the predominant species common to both regions and responsible for endo-perio lesions.

A reverse mechanism may also operate, with a pathway towards the pulp being in place.

Bloodstream

Bacteria may gain access to the pulp via the blood stream during transient bacterimias that occur following surgeries, extractions, root canal instrumentation, etc.

Bacteria which enter the bloodstream are usually destroyed by the defence mechanisms but some bacteria evenly localize out of the bloodstream into inflamed tissues. This phenomenon is called as Hematogenic anachoresis.

It is postulated that transient bacteremias in conjunction with the phenomenon of anachoresis may enamble blood-borne bacteria to infect unexposed, but previously injured pulps.

Microflora of Pulp Space (80% gram +ve)

The microbial flora of root canals and chamber generally similar to that of the oral cavity, with the following bacterial species are most common.

Streptococci

Alpha-hemolytic streptococci, commonly referred to as *S. viridans* are the most predominant species of streptococci isolated from infected root canals. They constitute about 5 percent of the total root canal flora, while other bacteria present being enterococci (25%), non-hemolytic streptococci (9%), *Streptococcus salivarius* (8%).

Staphylococci

They are the second most frequently isolated organisms from root canal cultures. The most commonly isolated species being *Staphylococcus epidermis*.

Other Gram +ve Bacteria

Pneumococci, Gaff kya, Sarcinae, Lactobacilli, Bacillus subtitis, Diphtheroids.

Gram -ve Bacteria

Neisseria, *Pseudomonas*, *E. coli*, *Veillonella* and *Bacteroids* (Porphyromonas).

A study conducted by WJ Dougherty, et al (1998, JO5) on the presence of block-pigmental bacteria (Porphyromonas) in coronal and apical segments of infected root canals, lead to the conclusion that most commonly occurring bacterias in coronal and apical thirds of infected root canals are the black pigmented bacteria, with, porphyomonas melanogenicus, *P. gingivalis*, *P. nigrescens* and *P. endodontalis* being most abundant.

Miscellaneous Microorganisms

- *Candida*
- *Actinomyces*
- *Nocardia*

Microflora of traumatized but intact teeth with necrotic pulps—mainly and predominantly consists of *B. melanogenicus* in association with other anaerobic bacteria.

Microflora of Acute Infections of Endodontic Origin

Consists of Bacteroides buccae in association with Bacteroids endodontalis, gingivalis and intermedius.

Microflora of Endodontic "Flare-up" Infections

Comprises mainly of endotoxin producing obligate anaerobis such as *Veillonella*, *Capnocytophaga*, *Eikenella*, *Bacteroides*, *Fusobacterium* and *Treponema*.

Bacteria in the Periradicular Space

Bacterial invasion of the dental pulp results in infection and eventual necrosis of the pulpal tissue. Bacteria then march down the free way of the root canal into periradicular region, in more than 68 percent of cases as stated by Hedman (1951). The importance of bacteria in the formation of periradicular disease was illustrated by Moller and associates. They stated that most commonly, bacteria that lead to the formation of periradicular pathologies were:

- Facultative anaerobic streptococci.
- Coliform rods
- Obligate anaerobes

Microbiology of periapical abscesses: Brook, et al (J Perio 96) periapical abscesses most commony harbors:

- *Fusobacteria nucleatum*
- *Prerotella intermedium*
- *Peptostreptococcus micros*
- *Peptostreptococcus prevotii*
- *Porphyromonas gingivalis*
- *Strep sanguis*
- *Strep milleri*

Microbiological Status of Root filled Teeth with Apical Periodontitis (Molander et al 98, IEJ)

Most frequently isolated genera in such a condition is Enterococci, i.e. Gram +ve facultative anaerobic cocci other than this,

- *Staph epidermidis*
- *Lactobacillus spp.*
- *E. coli* (Gram -ve facultative anaerobic rods)
- *Fusobacterium* spp. are commonly isolated.

Association of Specific Bacteria with Endodontic Signs and Symptoms Gomes and Drucker 94 (IEJ)

Association of bacterial species with pain:

- Gram -ve bacteria:
  - *Prerotella spp.*
  - *P. intermedia*
  - *P. melaninogenica*
- Gram +ve bacteria:
  - *Peptostreptococcus spp.*

Association of bacterial species with swelling:

- Gram -ve bacteria:
  - *Prerotella spp.*
  - *Fusobacterium necrophorum*
- Gram +ve bacteria:
  - *Peptostreptococcus spp.*
  - *P. micros*

Association of bacterial species with tenderness to percussion:

- *Actinomyces meyeri.*
- *Bacteroides gracilis*
- *L. casei*
- *Prerotella denticola*

Association of bacterial species with wet canal and purulent exudates:

- Wet canals
  - *Peptostreptococcus spp.*
  - *Prerotella spp.*
  - *Propionibacterium spp.*
- Purulent exudates
  - *Fusobacterium spp.*
  - *F. necrophorum*
  - *Prerotella buccae*
  - *P. loeschii*

SOME COMMONLY OCCURRING ORGANISMS

Streptococci (Fig. 5.6)

Four groups common in oral cavity.

- *S. mutans*
- *S. salivarius*
- *S. sangvis*
- *S. mitis*

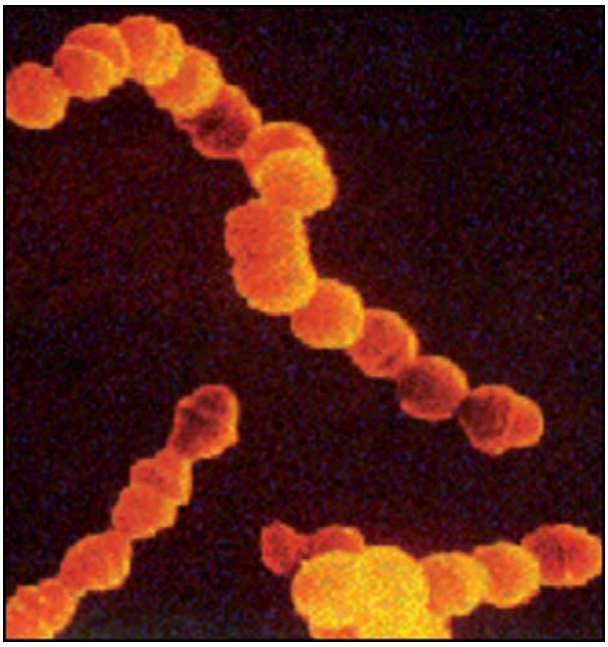


Fig. 5.6: Streptococci

S. Mutans

Group name for 7 different species (*S. mutans, S. sobrinus, S. cricetus, S. ferus, S. rattus, S. macacae* and *S. downei*).

Characterized by ability to ferment mannitol and sorbitol.

Evidence for association with caries:

1. Correlation between counts and caries
2. Isolated immediately before caries
3. With progression of caries
4. Produce dextran
5. Acidogenic
6. Aciduric
7. Rapid attainment of critical pH of enamel
8. Rapid metabolism of sugars
9. Produces intracellular glycogen
10. Immunization against it, reduced caries in animals.

S. Salivarius

- Most easily identified oral streptococci.
- Commonly found on tongue and saliva
- Indicator of salivary contamination.
- Forms "gum drop" colonies on mitis salivarius agar.
- Produces extracellular levan

S. Mitis

Most commonly found on non-keratinized mucosa.

S. Sanguis

- Sanguine (Iatin) - Blood
- Most commonly associated with endocarditis
- In oral cavity present on teeth and plaque
- Characterized by ability to convert arginine to NH_4 and CO_2.

Actinomyces (Fig. 5.7)

- Gram-positive anaerobic bacilli
- Associated with root surface caries and periodontitis
- Called sun ray fungus. Cluster together give an appearance of sulfur granule.

Lactobacilli (Fig. 5.8)

- Previously believed to be causative agents of caries
- High numbers in carious lesions
- Ability to grow in pH < 5
- Synthesise both intra- and extracellular polysaccharides
- Produce caries in gnotobiotic animals
- Low count in plaque in healthy sites.
- Specially associated with deep dentinal caries.

Veillonella (Fig. 5.9)

- Gram-negative anerobic cocci
- Present in supragingival plaque
- Require lactate for growth
- Convert lactate to weak acids (Possibly anticariogenic).

Enterococcus Faecalis (Figs 5.10A and B)

Enterococci occur as normal human commensal in the oral cavity and, gastrointestinal tract and is commonly used as an indicator for fecal contamination.

Although they make up only a small proportion of the initial flora of the untreated teeth with necrotic pulps, off late, *E. faecalis* have been frequently found in obturated root canals exhibiting signs of chronic apical periodontitis and in retreatment cases. They now rank among the top three nosocomial pathogens accounting for up to 12 percent of the nosocomial infections.

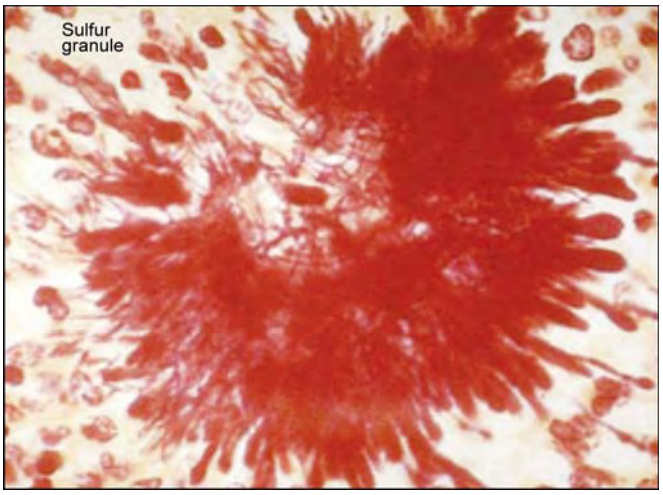


Fig. 5.7: Sulfur granule

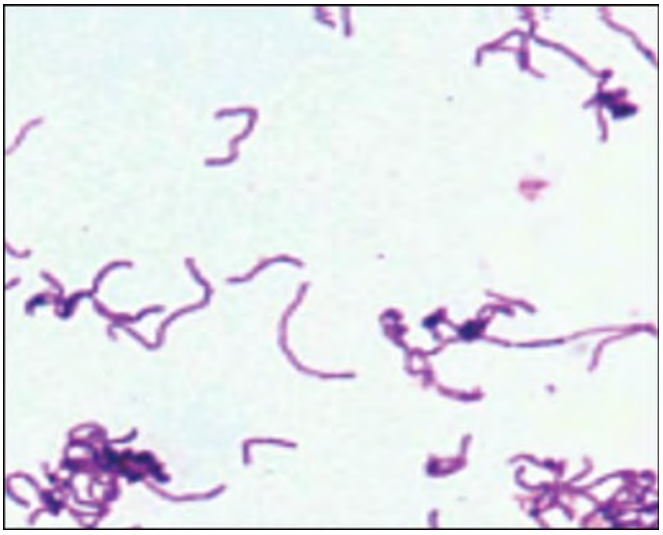


Fig. 5.8: Lactobacilli

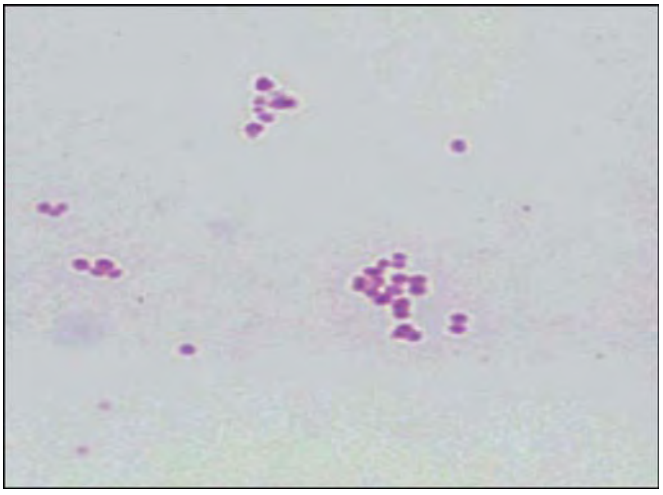
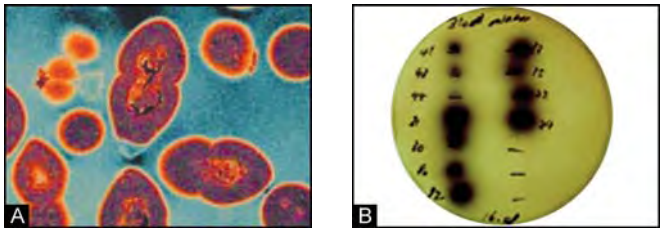


Fig. 5.9: Veillonella



Figs 5.10A and B: (A) *Enterococcus faecalis* (B) Growth on bile esculin

These are Gram-positive, catalase- negative spherical or oval cocci in pairs at an angle or short chain.They are identified by their ability to grow in 40 percent bile and 6.5 percent sodium chloride, at pH 9.6, and temperature ranging from 10ºC to 45ºC. Growth on bile-esculin is one of the characteristic feature used to identify enterococci where they stain the agar brownish black.

The virulence of *E. faecalis* is due to various factors like:

- They can withstand very harsh environmental conditions and, survive for 30 min at 60 degrees
- In vitro studies, have shown that *E. faecalis* can invade deep into the dentinal tubules and thus can survive chemomechanical instrumentation and intracanal medication. These organisms can then recolonize the tubules and reinfect the obturated root canal.
- It is resistant to antimicrobial effects of calcium hydroxide, probably due to an effective proton pump mechanism which maintains optimal cytoplasmic pH levels.
- *E. faecalis* is also resistant to a wide range of antibiotics which if used may shift the microbial flora in favor of *E. faecalis*.
- They occur with other gram-positive organisms in a biofilm which further makes them resistant to antibiotics.

This resistance can be due to:

1. Slow penetration of the medicament through biofilm.
2. There may be changes in the chemical environment of the biofilm like:
   a. Some antibiotics require aerobic condition to be effect
   b. Acidic by products can cause a difference in pH and thus an antagonizing effect on the antibiotics.
   c. Changes in osmotic conditions within the biofilm can result in osmotic stress response which lead to changes in relative proportion of porins, and thus permeability to antibiotics is reduced.
3. It has also been suggested that in a bio-film, a subpopulation of the organisms are in a phenotypic state wherein they are highly protected with the cell differentiation being similar to spore formation which results in decreased susceptibility to antibiotics.
   - Enterococci adhere to the fibronectin and collagen fibers in dentin (both mineralized and unmineralized) by help of adhesins like Ace protein and Aggregation Substance.
   - Enterococci show a stress response i.e. in absence of nutrition, they develop into a resistant phenotype wherein the rate of protein synthesis will decrease; but the synthesis of "starvation induced proteins" will continue which is important in protection of the cell against different stress challenges such as heat, hydrogen peroxide, acidity, salt, sodium hypochlorite, bile salts and sodium dodecyl sulfate (SDS). They reach a stationary growth phase. With increasing time of starvation, the cell size will decrease and in long-term starvation they may reach a minimum.
   - The viable but non-culturable (VBNC) state: After long periods of starvation, the number of culturable cells will decrease while the total number of bacteria remains the samel. This was thought to be because of the death of the organisms and therefore not culturable. However, recent studies have shown that the cells enter a state in which they are viable but non-culturable with standard microbiological techniques. *E. faecalis* is said to exhibit this VBNC state, but further studies have to be done to confirm this state.
   - They can survive in a highly alkaline medium with pH as high as 11.5.
   - Alter host responses by suppressing the action of lymphocytes.

E. faecalis is found to be susceptible to the following irrigants:

- MTAD with NaOCI for 5 min
- 0.2 percent chlorhexidine liq for 30s (by Gomes)

- Ca (OH)2 + CMCP (by Sukawat & Srisuwan)
- 2-4 percent IKI.

CULTURE METHODS AND MEDIA

Bacteria have to be grown for them to be identified, as only rarely can they be recognized by morphology alone. By appropriate procedures they have to be grown separately on culture media and obtained as pure cultures for study.

Numerous culture media have been devised, ever since the first original media was used by Louis Pasteur, who used urine or meat broth as culture media. These culture media were liquid in consistency and had the disadvantage that isolation of pure cultures was not possible. Later Robert Koch used cooked cut potato as earliest solid media and also experimented by addition of gelatin to liquid media in order to solidify.

Then an effective method to produce solid culture media, was introduced, when Frau Hesse, used agar in place of gelatin.

Constituents of Culture Media

- Agar (2%)
- Peptones
  - Proteases
  - Polypeptides
  - Amino acids
  - Inorganic salts such as PO_4^-, K^+, Mg^+
  - Accessory growth factors: Riboflarin
- Meat extract
- Blood, serum, yeast extract.

Types of Culture Media

Media have been classified into:

A. According to consistency of media:
   - Solid media
   - Liquid media
   - Semisolid media.

B. According to constituents of media:
   1. Simple media
   2. Complex media
   3. Synthetic or defined media
   4. Semidefined media
   5. Special media:
      - Enriched media
      - Enrichment media
      - Selective media
      - Indicator or differential media
      - Sugar media
      - Transport media

C. According to type of bacterial growth they support:
   - Aerobic media
   - Anaerobic media.

Simple Media

Composition:
- Peptone
- Meat treatment
- NaCl + H_2O
- Agar:
  0.2-0.5 percent: Semisolid media
  2 percent: Solid media: Routine diagnostic tests
  6 percent: Hard media: For *Proteus* spp.
  Example: Nutrient agar.

Complex Media

Simple media in addition to nutrients specific for specific types of bacteria is called as complex media.

Synthetic or Defined Media

Prepared purely from chemical substances, e.g. Simple peptone water medium (1% peptone + 0.5% NaCl in water).

Enriched Media

Substances such as blood, serum or egg are added to simple media, e.g. Blood agar, chocolate agar, egg agar.

Enrichment Media

It is simple media that is added upon by various enzyme complexes, which inhibit the growth of unwanted bacteria but promote the growth of wanted bacteria, e.g. Tetrathionate broth (inhibits coliforms, increase typhii), Selenite F broth.

Selective Media

In this type of media, substances/chemicals that inhibited the growth of unwanted bacteria are added to simple media, e.g. Desoxy cholate citrate medium.

Indicator Media

These media contain an indicator, which changes color when a type of bacterium grows in them, e.g. Addition of sulphite to Wilson-Blair medium.

Differential Media

A medium which has substances incorporated in it, enabling it to bring out differing characteristics of bacteria and thus, helping to distinguish between them, e.g. MacConkey's medium: It consists of: Peptone, Lactose, agar, neutral red and taurocholate.

Lactose fermenters: grow as pink colonies.

Non-lactose fermenters: colorless colonies.

Transport Media

Organisms that do not survive the time taken for transporting the specimens are transported in special media called as transport media, e.g. Stuart's medium.

Anaerobic Media

Media used to grow anaerobic microorganisms, e.g. Robertson's cooked meat media.

Culture media of endodontic significance are:

- Brain- heart infusion broth, with 0.1 percent agar
- Typicase-soy broth, with 0.1 percent agar
- Thioglyoollate broth
- Glucose-ascitis broth

ROOT CANAL CULTURES

Various clinical and experimental studies have reported to state that on an average, a greater success rate of approximately 10 percent can be achieved in endodontics, when canals are obturated only after negative cultures.

Advantages of Culturing Root Canals Samples

1. A negative culture is most reliable index of root canal sterility available to dentists.
2. Root canal cultures provide valuable feedback information to the dentist.
3. Cultures make it possible to identify the antibiotic sensitivity of canal organisms, early, in the course of treatment.
4. Culture is one of the important criterions that determine the time of obturation.

Disadvantages

1. Need to purchase bacteriologic incubator.
2. Need to purchase and stock culture media.
3. Inconvenience of taking, labeling, reading and recording of culture results.
4. Prolongs treatment span.

Culturing Technique

Steps in culturing root canal flora:

1. Isolate the tooth and disinfect using a germicidal solution.
2. Gain access to the pulp chamber, remove necrotic debris, pulp.
3. Insert absorbent point into approximately the upper one-third of canal(s) and permit tip portion to be moistened by canal contents.

   If dry, canal orifices may be moistened with one drop of sterile saline or local anesthetic solution to assure obtaining an adequate inoculum.
4. Flame lip of culture tube and drop impregnated absorbent point into culture medium.

   Place inoculated tubes in bacteriologic incubator 37°C for a minimum of 48 hours.
5. After 48 hours of incubation, examine culture, cloudiness of the media is indicative of microbial growth, i.e. a positive root canal culture.

Culture Characteristics of Microorganisms of Interest

1. *Streptococcus: Culture media required:* Mitis salivarius agar (MSA). It is a selective media.
   Strep. Mutans: MSA + bacitracin
   High convex, opaque colonies
   Strep. oralis: MSA
   Small, soft, non-adherent colonies
   Strep. salivaris: MSA
   Large mucoid colonies
   Strep. milleri: MSA + sulphonamide
   Small, non-adherent colonies.
2. *Lactobacillus casei, L. fermentum:* Rogosa agar medium + acetic acid.
3. *Actinomyces:* Blood agar medium
   A. israelii: Molar tooth colony
   A.odontolyticus: Small round colonies with reddish brown center
4. *Micrococcus + Staphylococcus:* Blood agar medium
   Micrococcus mucilagenosus: Large colonies adherent to surface of medium
   Staph. aureus: Large, yellow pigmented colonies
5. *Veillonella:* Rogesa's vancomycin agar
6. *Haemophillus, Parainfluenzae:* Heated blood agar/ chocolate medium.
7. *Actinobacillus actinomycetemcomitans:* Selective media containing vancomycin and bacifracin.

8. *Eikenella corrodens:* Blood agar medium,
   Corroding colonies on medium.
9. *B. gingivalis, Bacteroids intermedius:* Blood agar medium
   Require vit K and haemin for growth
   Black pigmented colonies
   Bacteroids oralis: Nonpigmented colonies.
10. *Treponema denticola:* Enriched simple media with serum
    T. macrodentium, T. ovale: Colonization is poor
    T. vincentii: Confusing
11. *Entamoeba gingivalis:* Complex media.
12. *Candida albicans:* Sabouraud's medium - Creamy white colonies.
13. *Mycoplasma orale; M. salivarium:* Soft-nutrient agar with 20 percent serum, DNA, penicillin and thallous acetate. Minute colonies, 0.1-1 mm in diameter, barely visible to naked eye.

MICROBIOLOGICAL DIAGNOSIS IN ENDODONTICS

Endodontic infections have been traditionally studied by culture-dependent methods. As with other areas of clinical microbiology, culture-based investigations are plagued by significant problems, including the probable involvement of viable but uncultivable microorganisms with disease causation and inaccurate microbial identification. Innumerous molecular technologies have been used for microbiological diagnosis in clinical microbiology, but only recently some of these techniques have been applied in endodontic microbiology research. Moreover, advantages and limitations of current molecular techniques when compared to conventional methods for microbial identification are also discussed.

Traditional Identification Methods

Culture

During olden days, cultivation using artificial growth media has been the standard diagnostic test in infectious diseases. Making microorganisms grow under laboratory conditions presupposes some knowledge of their growth requirements. Very little is known about the specific growth factors that are utilized by microorganisms to survive in all habitats within the human body. A huge proportion of the microbial species in nature are difficult to be studied in the laboratory. Certain bacteria are fastidious or even impossible to cultivate.

Reasons for bacterial unculturability

a. Lack of essential nutrients or growth factors in the artificial culture medium.
b. Toxicity of the culture medium itself, which can inhibit bacterial growth.
c. Production of substances inhibitory to the target microorganism by other species present in a mixed consortium.
d. Metabolic dependence on other species for growth.
e. Disruption of bacterial intercommunication systems induced by separation of bacteria on solid culture media.
f. Bacterial dormancy, which is a state of low metabolic activity that some bacteria develop under certain stressful environmental conditions, such as starvation. Dormant bacterial cells can be unable to divide or to form colonies on agar plates without a preceding resuscitation phase.

Advantages

1. Broad-range nature, possible to identify a great variety of microbial species in a sample.
2. It possible to determine antimicrobial susceptibilities of the isolates and to study their physiology and pathogenicity.

Limitations

1. They are expensive.
2. They can take several days to weeks to identify some fastidious anaerobic bacteria.
3. They have a very low sensitivity and specificity and is dependent on the experience of the microbiologist.
4. They have strict dependence on the mode of sample transport; they are time-consuming and laborious.
5. Impossibility of cultivating a large number of bacterial species as well as the difficulties in identifying many cultivable species represents the major drawbacks of cultivation-based approaches.

Microscopy

Microscopy has limited sensitivity and specificity to detect microorganisms in clinical samples. Limited sensitivity is because a relatively large number of

microbial cells are required before they are seen under microscopy (e.g.104 bacterial cells/ml of fluid). Some microorganisms can even require appropriate stains and/or approaches to become visible. Limited specificity is because our inability to identify microorganisms based on their morphology and staining patterns.

Immunological Methods

Immunological methods are based on the specificity of antigen antibody reaction. It can detect microorganisms directly or indirectly, the latter by detecting host immunoglobulins specific to the target microorganism.

Most commonly used immunological methods for microbial identification are:

1. ELISA
2. Direct or indirect immunofluorescence tests.

Advantages of Immunological Methods

a. They take no more than a few hours to identify a microbial species.
b. They can detect dead microorganisms.
c. They can be easily standardized.
d. They have low cost.

Limitations

1. They can detect only target species,
2. They have low sensitivity (about 104 cells).
3. Their specificity depends on types of antibodies used, and their detection of dead microorganisms.

Molecular Genetic Methods (Fig. 5.11)

A significant contribution of molecular methods to medical microbiology relates to the identification of previously unknown human pathogens. Novel culture-independent methods for microbial identification that involve DNA amplification of 16S rDNA followed by cloning and sequencing have recently been used to determine the bacterial diversity within diverse environments, Molecular diagnostic methods have several advantages over other methods with regard to microbial identification.

Types

1. Polymerase chain reaction (PCR).
2. Denaturing gradient gel electrophoresis (DGGE)
3. Terminal restriction fragment length polymorphysm.
4. Fluorescence in situ hybridization (FISH).

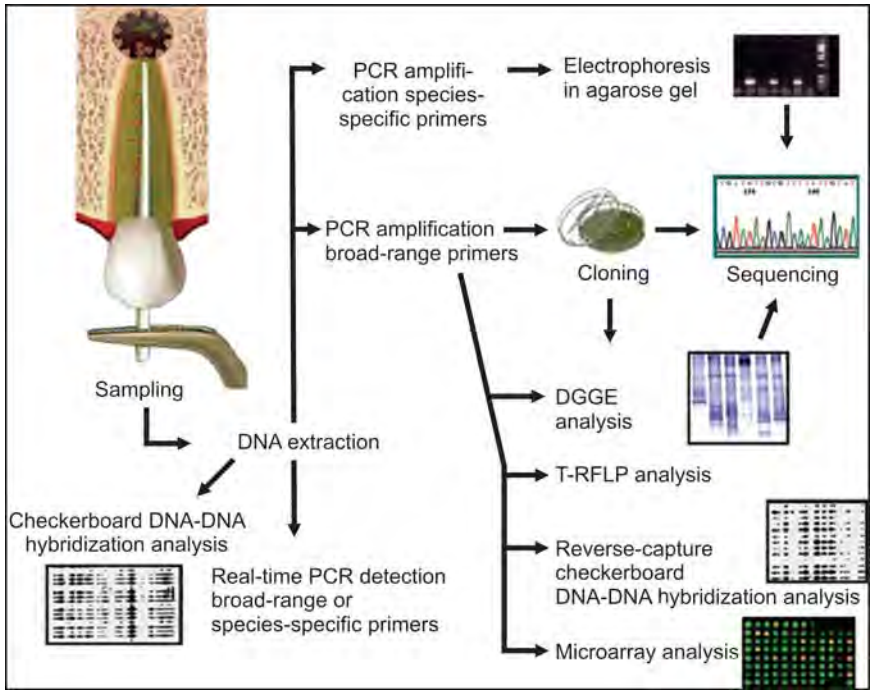


Fig. 5.11: Schematic representation of various molecular diagnostic methods (adopted from JOE)

Advantages of Molecular Genetic Methods

a. Detection of not only cultivable species but also of uncultivable microbial species or strains.
b. Higher specificity and accurate identification of microbial strains with ambiguous phenotypic behavior, including divergent or convergent strains.
c. Detection of microbial species directly in clinical samples, without the need for cultivation.
d. Higher sensitivity.
e. Faster and less time-consuming.
f. They offer a rapid diagnosis, which is particularly advantageous in cases of life-threatening diseases or diseases caused by slow growing micro-organisms.
g. They do not require carefully controlled anaerobic conditions during sampling and transportation, which is advantageous since fastidious anaerobic bacteria and other fragile microorganisms can lose viability during transit.
h. They can be used during antimicrobial treatment.
i. When a large number of samples are to be surveyed in epidemiological studies, samples can be stored and analyzed all at once.

Gene Targets for Microbial Identification

The gene to be used as target for microbial identification should contain regions that are unique to each species. Large subunit genes (23S and 25S rDNA) and small subunit genes (16S and 18S rDNA) have been widely used for microbial identification, characterization and classification. 16S rDNA is the most useful target for bacterial identification by molecular approaches, and 23S rDNA is becoming a suitable alternative (Fig. 5.12).

POLYMERASE CHAIN REACTION (FIG. 5.13)

The PCR process was designed by Kary Mullis in 1983 and since then has revolutionized the field of molecular biology. The PCR method is based on the *in vitro* replication of DNA through repetitive cycles of denaturation, primer annealing and extension steps. Numerous derivatives in PCR technology have been developed since its inception.

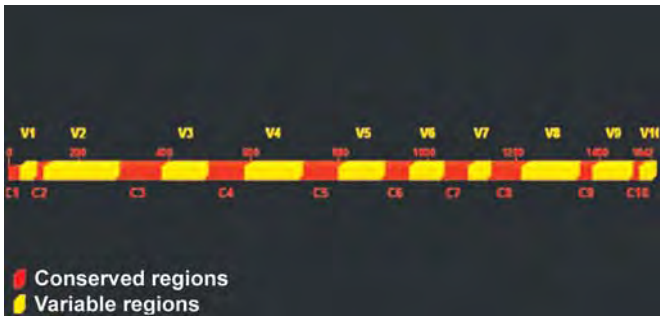


Fig. 5.12: Schematic diagram of 16-s rDNA gene

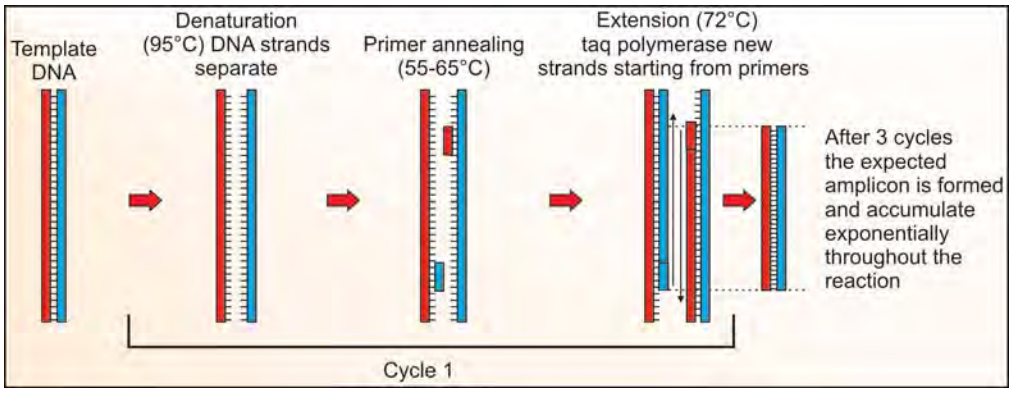


Fig. 5.13: Scheme for PCR

Types of PCR

1. Nested PCR
2. Reverse Transcriptase PCR (RT-PCR)
3. Multiplex PCR
4. Real-Time PCR
5. Broad-Range PCR

Nested PCR

Nested PCR uses the product of a primary PCR amplification as template in a second PCR reaction and was devised mainly to have increased sensitivity. The major drawback of nested-PCR protocol is the high probability of contamination during transfer of the first-round amplification products to a second reaction tube and special precautions should be taken to avoid this.

Reverse Transcriptase PCR (RT-PCR)

RT-PCR was developed to amplify RNA targets and exploits the use of the enzyme reverse transcriptase, which can synthesize a strand of complementary DNA (cDNA) from an RNA template. Most RT-PCR assays employ a two-step approach. In the first step, reverse transcriptase converts RNA into single-stranded cDNA. In the second step, PCR primers, DNA polymerase, and nucleotides are added to create the second strand of cDNA.

Multiplex PCR

Most PCR assays have concentrated on the detection of a single microbial species by means of individual reactions. In multiplex PCR, two or more sets of primers specific for different targets are introduced in the same reaction tube. Since more than one unique target sequence in a clinical specimen can be amplified at the same time, multiplex PCR assays permit the simultaneous detection of different microbial species.

Real-time PCR

Real-time PCR assays allow the quantification of individual target species as well as total bacteria in clinical samples. The advantages of real-time PCR are the rapidity of the assay (30-40 min), the ability to quantify and identify PCR products directly without the use of agarose gels, and the fact that contamination of the nucleic acids can be limited because of avoidance of post-amplification manipulation.

Broad-range PCR

PCR technology can also be used to investigate the whole microbial diversity in a given environment. In broad-range PCR, primers are designed that are complementary to conserved regions of a particular gene that are shared by a group of microorganisms. For instance, primers that are complementary to conserved regions of the 16S rDNA have been used with the intention of exploiting the variable internal regions of the amplified sequence for sequencing and further identification.

Method of Culture Taking for PCR Analysis (Fig. 5.14)

Denaturin G Gradient Gel Electrophoresis

In DGGE, DNA fragments of the same length but with different base-pair sequences can be separated. The DGGE technique is based on electrophoresis of PCR-amplified 16S rDNA (or other genes) fragments in polyacrylamide gels containing a linearly increasing gradient of DNA denaturants (a mixture of urea and

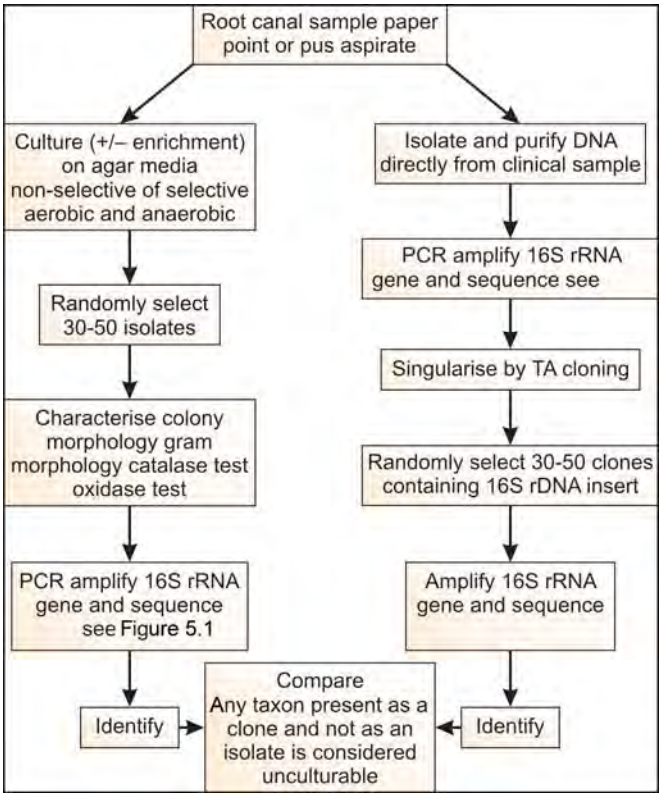


Fig. 5.14: Strategy defining the unculturable microbiota in a root canal sample

formamide). As the PCR product migrates in the gel, it encounters increasing concentrations of denaturants and, at some position in the gel, it will become partially or fully denatured. Partial denaturation causes a significant decrease in the electrophoretic mobility of the DNA molecule. DNA bands in DGGE can be visualized using ethidium bromide, SYBR Green I, or silver staining.

In DGGE, multiple samples can be analyzed concurrently, making it possible to compare the structure of the microbial community of different samples and to follow changes in microbial populations over time, including after antimicrobial treatment. Specific bands can also be excised from the gels, re-amplified and sequenced to allow microbial identification. The Temperature gradient gel electrophoresis (TGGE) uses the same principle as DGGE, except for the fact that the gradient is temperature rather than chemical denaturants.

Terminal-RFLP

T-RFLP is a recent molecular approach that can assess subtle genetic differences between microbial strains as well as provide insight into the structure and function of microbial communities. This analysis measures the size polymorphism of terminal restriction fragments from a PCR amplified marker.

In T-RFLP, rDNA from different species in a community is PCR amplified using one of the PCR primers labeled with a fluorescent dye, such as 4, 7, 2′, 7′ tetrachloro-6-carboxyfluorescein (TET) or phosphoramidite fluorochrome 5-carboxyfluorescein (6-FAM). PCR products are then digested with restriction enzymes, generating different fragment lengths. Digestion of PCR products with judiciously selected restriction endonucleases produces terminal fragments appropriate for sizing on high resolution sequencing gels. The latter step is performed on automated systems such as the ABI gel or capillary electrophoresis systems that provide digital output. T-RFLP has considerably greater resolution than gel-based community profiling techniques, such as DGGE/TGGE.

DNA-DNA Hybridization

DNA-DNA hybridization methodology employs DNA probes, which consists of segments of single-stranded DNA, labeled with an enzyme, radioactive isotope or a chemiluminescence reporter, that can locate and bind to their complementary nucleic acid sequences. DNA-DNA hybridization arrays on macroscopic matrices, such as nylon membranes, have been often referred to as "macroarrays." DNA probe may target whole genomic DNA or individual genes.

Socransky et al introduced a method for hybridizing large numbers of DNA samples against large numbers of digoxigenin-labeled whole genomic DNA or 16S rDNA-based oligonucleotide probes on a single support membrane the checkerboard DNA-DNA hybridization method.

The checkerboard method permits the simultaneous determination of the presence of many bacterial species in single or multiple clinical samples. DNA-DNA hybridization technology has the additional feature that microbial contaminants are not cultivated, nor is their DNA amplified.

DNA Microarrays

Microarray methods were first described in 1995 and essentially consist of many probes that are discretely located on a nonporous solid support, such as a glass slide. Printed arrays and high-density oligonucleotide arrays are the most commonly used types of microarrays. Probes can be DNA fragments such as library clones or PCR products. By means of a robotic arrayer and capillary printing tips, thousands of elements can be printed on a single microscope slide.

Microarrays have been used to analyze the genetic polymorphisms of specific loci associated with resistance to antimicrobial agents, to explore the distribution of genes among isolates from the same and similar species, to analyze quorum-sensing systems, to understand the evolutionary relationship between closely related species and to study host-pathogen interactions.

Fluorescence in situ Hybridization

Fluorescence in situ hybridization (FISH) with rRNA-targeted oligonucleotide probes has been developed for *in situ* identification of individual microbial cells. This technique detects nucleic acid sequences by a fluorescently labeled probe that hybridizes specifically to its complementary target sequence within the intact cell. In addition to provide identification, FISH gives

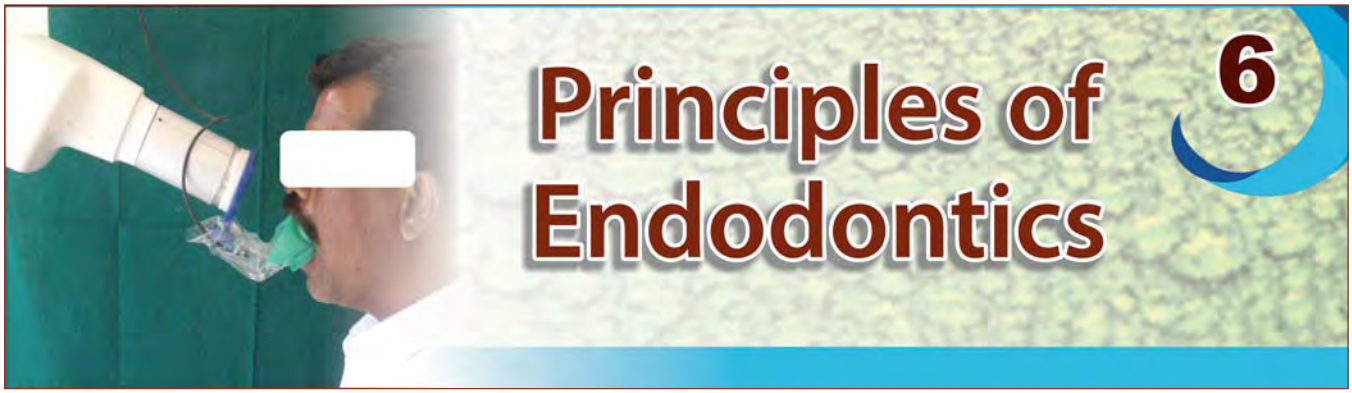
information about presence, morphology, number, organization and spatial distribution of micro-organisms. FISH allows the detection of cultivable and uncultivable microbial species.

Limitations of PCR-derived Technologies

a. Most PCR assays used for identification purposes qualitatively detect the target microorganism but not its levels in the sample. Quantitative results can however be obtained in real-time PCR assays.
b. Most PCR assays only detect one species or a few different species (multiplex PCR) at a time. However, broad-range PCR analysis can provide information about the identity of virtually all species in a community.
c. Like DNA-DNA hybridization, most PCR assays only detect target species and fail to detect unexpected species. This can be overcome by broad-range PCR assays.
d. PCR assays laborious and costly.
e. Assay for microorganisms with thick cell walls, such as fungi, may be difficult.
f. False positive results have the potential to occur because of PCR amplification of contaminant DNA.
g. False negatives may occur because of enzyme inhibitors or nucleases present in clinical samples.

SUGGESTED READING

1. Association reports: current status of sterilization instruments, devices, and methods for the dental office; JADA 1981;102:683-89.
2. Charles H Stuart. Enterococcus Faecalis: Its role in root canal treatment failure and current concepts in retreatment; J Endodon 2006;32(2):93-98.
3. Chris H Miller. Cleaning, Sterilization and Disinfection; JADA; 1993;24:48-56.
4. Chris H Miller. Sterilization and disinfection; JADA 1992;123:46-54.
5. Denis P Lynch. Oral candiasis- History, classification, and clinical presentation; Oral Surg Oral Med Oral Patho 1994;78:189-93.
6. David A Spratt. Significance of bacterial identification by molecular bilogy methods; endodontic topics 2004;9:5-14.
7. Ehrmann. Focal infection- The endodontic point of view; Surg Oral Med Oral Path; 1997;44(4).
8. Goran Sundquist. Taxonomy, ecology,and pathogenicity of the root canal flora; Oral Surg Oral Med Oral Pathol 1994;78;522-30.
9. Guven Kayaglu. Virulence factors of Enterococcus Faecalis: Relationship to endodontic disease; Crit Rev Oral Bio Med 2004;15(5):308-20.
10. Gilberto J Debelian. Systemic diseases caused by oral microorganisms; Endod Dent Traumatol 1994;10:57-65.
11. Howard K Kuramiitsu. Virulence factors of mutans streptococci: Role of molecular genetics; Crit Rev Oral Bio Med 1993;4(2);159-76.
12. Isabelle Portenier, Tuomos MT. Waltimo: Enterococcus Faecalis—the root canal survivior and 'star' in post-treatment disease. Endodontic topics 2003;6:135-59.
13. Jose F Siqueira Jr. Taxonomic changes of bacteria associated with endodontic infections. J Endodon 2003;29(10):619-23.
14. Jose F Siqueira Jr. Fungi in endodontic infection. Oral Surg Oral Med Oral Patho 2004;97:632-41.
15. Jose F Siqueira Jr. Exploiting the molecular methods tp explore endodontic infections: part 1—current molecular technologies for microbial diagnosis. J Endodon; 2005; 31(6):411-21.
16. Jose F Siqueira Jr. PCR methodology as a valuable tool for identification of endodontic pathogen. J Dent; 2004;31:333-39.
17. Moksha Nayak;Mithra Hegde. Molecular diagnostic methods in endodontics. Endodontology 2006;Vol18(2):35-42.
18. Muerman. Dental infections and general health; Quintessence Int 1997;28(12):807-10.
19. Murray and Saunders. Root canal treatment and general health. Int Endodon J, 2000;33:1-18.
20. Robert J, Berkowitz. Acquisition and transmission of Mutans streptococci. Journal of California Dental Association 2003;31(2):135.
21. Rocas Jose F. Siquiera Jr: Association of enterococcus faecalis with different forms of periradicular diseases ; J Endodon; 2005;30(5):315-20.
22. Roberts. Bacteria in the mouth; Dental update; 2005;32:134-42.
23. Suchitra U. Enterococcus faecalis: An endodontic pathogen; Endodontology 2006,18(2):11-13.
24. Thomas J. Pallasch: Focal infection: New age or ancient history; endodontic topics; 2003;4:32-45.
25. Waltimo, et al. Yeasts in apical periodontitis; Crit Rev Oral Bio Med; 2003;14(2):128-37.



1. Case selection
2. Isolation
3. Sterilization

CASE SELECTION

This topic has already been discussed in Diagnosis chapter. Here only relevant points are discussed.

- Oral hygiene
- Patient's interest in dental treatment
- Success and longevity of final restoration
- Interpretation of radiographic findings

Oral Hygiene

It plays an important role in endodontics. Patients with poor oral hygiene have lower success rate. Before planning endodontic treatment, it is better to advise oral prophylaxis and preventive measures like fluoride mouth rinses.

Patient's Interest in Dental Treatment

Patient should be motivated before starting treatment. They should be thoroughly explained about endodontic treatment, its success and failure. Some patients may not understand the importance of endodontic treatment. We should try to convince these patients about advantage of saving natural tooth over extraction. In spite of this, if a patient does not agree for endodontic treatment, then any alternative treatment can be considered.

Success and Longevity of Final Restoration

Longevity plays an important role in case of endodontic treatment. Endodontic therapy is a time consuming process and is expensive. Sometimes, referral to other specialties may be required to enhance the likelihood of success.

Interpretation of Radiographic Findings (Figs 6.1A and B)

This plays a very important role in the success of endodontic treatment. Radiograph reveals the

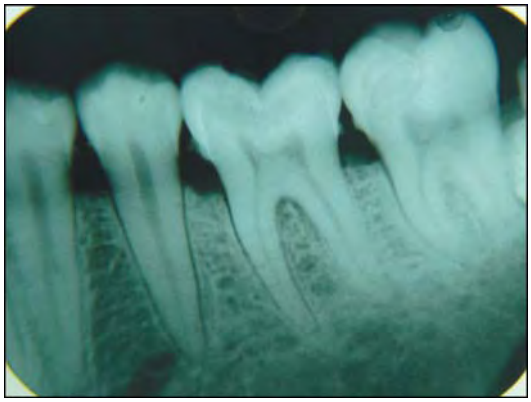


Fig. 6.1A: Radiograph showing normal features

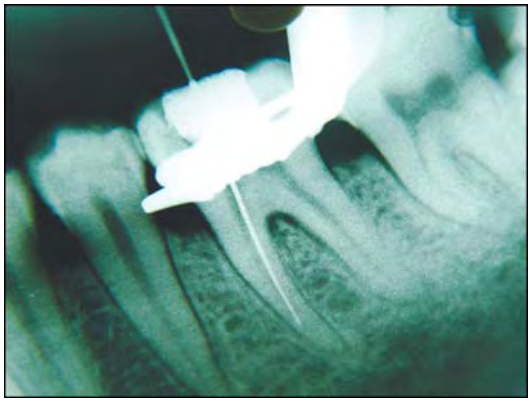
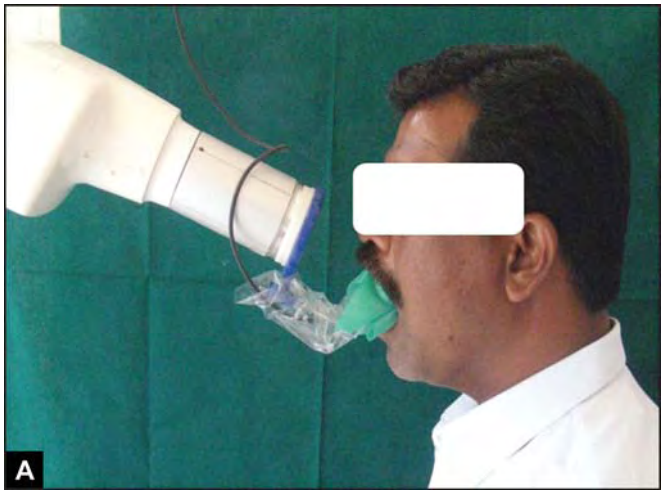


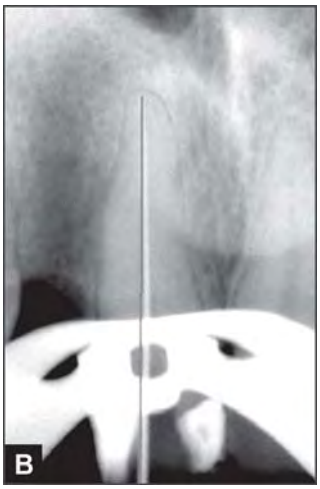
Fig. 6.1B: Radiograph showing ledge formation

anatomy of root canal which cannot be seen by naked eye. Not only canal morphology, it gives information and reveals pathological lesions in the canal as well as the surrounding areas. Intraoral radiographs play major role in this direction. But there are certain disadvantages like overlapping of images. These can be overcome by using paralleling technique.

Bisecting angle technique	*Paralleling technique*
1. This is easy and comfortable to the patient	1. It causes discomfort to the patient
2. This can be used along with the rubber dam	2. This is difficult to use when the rubber dam is placed
3. This can be used in all cases (even with small mouth openings)	3. Cannot be used in cases with small mouth openings
4. Distortion of the radiograph can occur	4. This is distortion free
5. Frequently overlapping or super imposition of the zygomatic bone on the apices of the maxillary molars makes it difficult to read the radiograph	5. There is no super imposition. The apices of maxillary molar can be easily read (lie below the zygomatic arch)
6. Comparison with previous radiographs is difficult, as it is difficult to reproduce the same landmarks.	6. Comparison with previous radiographs is easy.

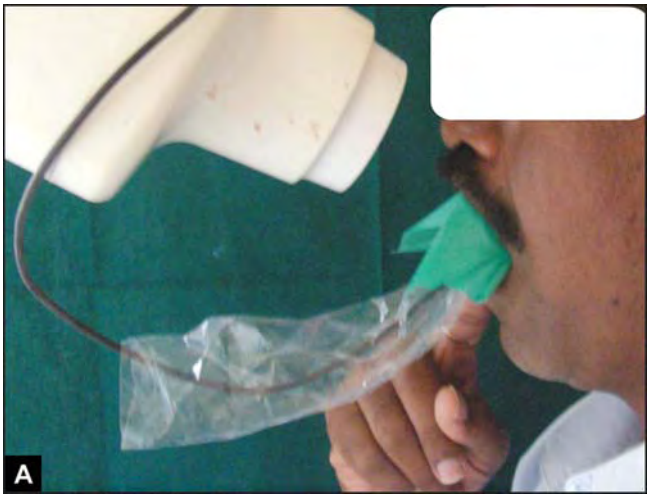
Paralleling Technique (Figs 6.2A and B)

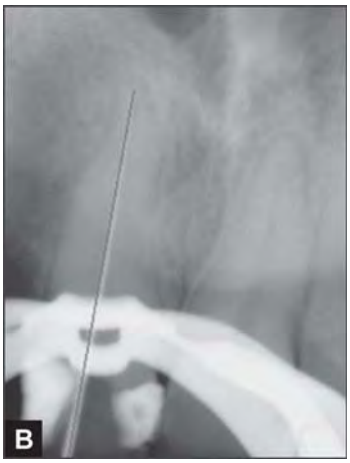




Figs 6.2A and B: Paralleling techniques

Bisecting Angle Technique (Figs 6.3A and B)





Figs 6.3A and B: Bisecting angle technique

ISOLATION

Isolation is very important to prevent infection during endodontic treatment. There are various methods of isolation:

- Rubber dam
- Cotton rolls
- Saliva ejectors
- High vacuum suction.

Rubber Dam

Commonly used modality for isolation during endodontic treatment is rubber dam. First introduced in the endodontic practice by SC Barnum.

The functions of Rubber dam are:

1. To prevent contamination by saliva.
2. To prevent slipping of instrument into the throat (ingestion of instruments).
3. Prevent contamination between the patient and dentist.
4. Reduces aerosol contamination and cross-infection by up to 98.5 percent.
5. It prevents the strong irrigating solutions and medicaments contacting oral mucosa.

The components of rubber dam (Figs 6.4A and B):

1. Rubber dam frame
2. Rubber dam sheets
3. Rubber dam punch
4. Rubber dam clamp holder
5. Rubber dam clamps for posterior and anterior teeth
6. Rubber dam template.

Rubber dam frame: There are various types of Rubber dam frames:

1. Round - e.g: Nyagard-Ostby
2. U shaped

Materials may be:

1. Plastic (Fig. 6.5)
2. Metal (Fig. 6.6)

And some frames are incorporated with Rubber dam sheet known as Insta dam (Fig. 6.7).

- The function of frame is to stabilize the dam in proper position.
- There are two methods:
  1. Frame is placed below the Rubber dam
  2. Frame is placed above the Rubber dam

Frame placement below the Rubber dam is much easier as it prevents injury to the patient's face.

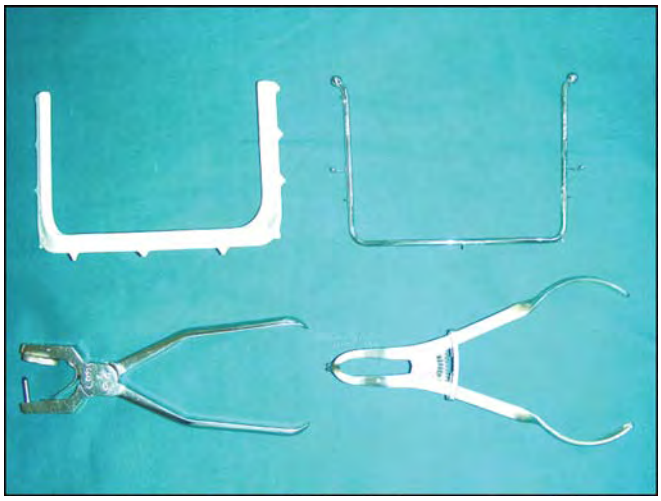


Fig. 6.4A: Rubber dam armamentarium

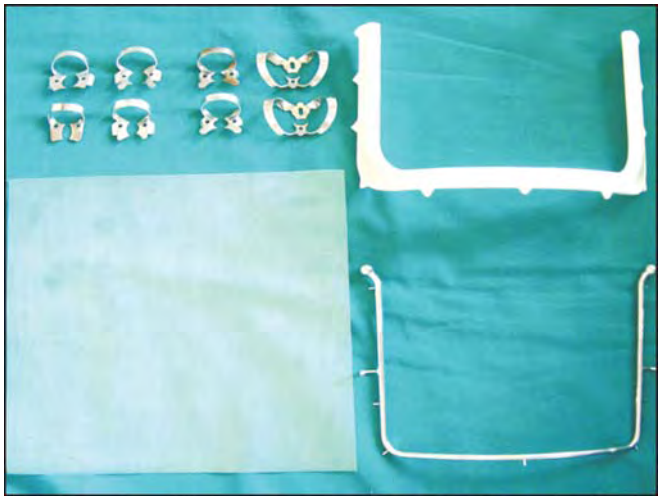


Fig. 6.4B: Components of rubber dam Kit

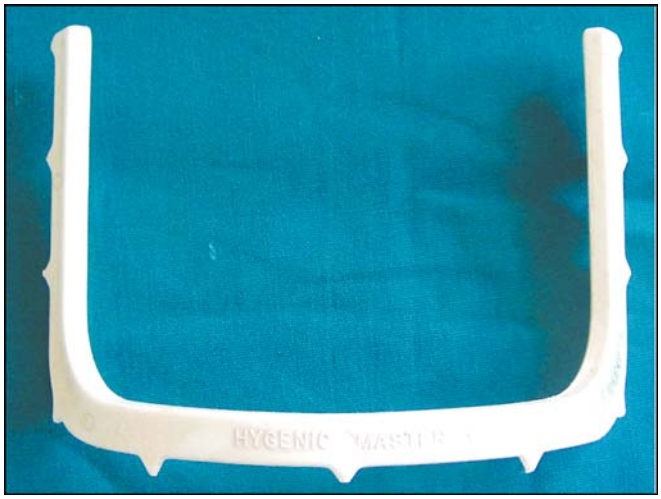


Fig. 6.5: Hygienic plastic frame

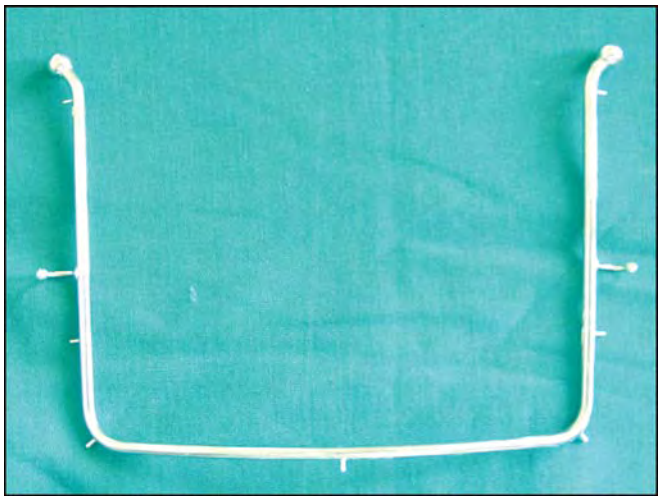


Fig. 6.6: Young's frame

Fig. 6.8: Rubber dam sheet 6 × 6"

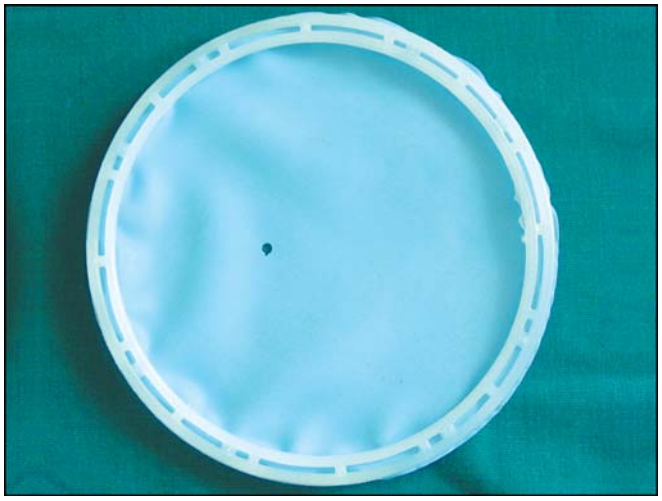


Fig. 6.7: Insta dam

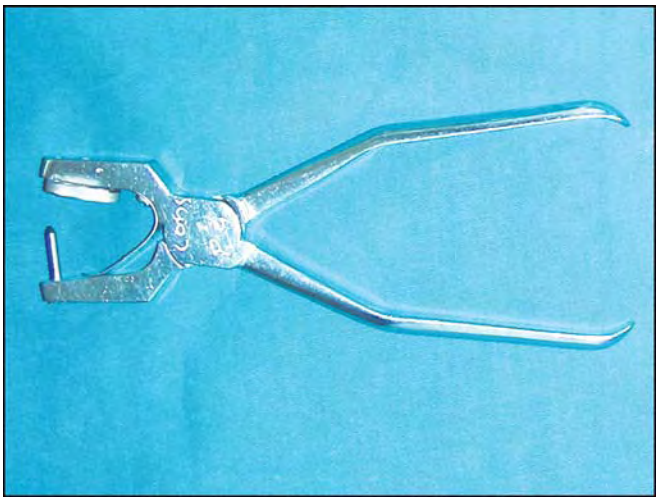


Fig. 6.9: Rubber dam punch

Rubber Dam Sheets (Fig. 6.8)

- Rubber dam sheets are available in different colors and shades, so that the contrast between the rubber dam and oral structures can be easily made.
- There are 2 size of rubber dam:
  1. 6 × 6″ - Adult
  2. 5 × 5″ - Pedodontics

Depending on thickness rubber dam sheets are classified as- Light, medium, heavy and extra heavy.

Rubber Dam Punch (Fig. 6.9)

It is a metal punch containing holes of various sizes which are meant for individual tooth size as well as clamp size.

Rubber dam clamps (Fig. 6.10) are available in various sizes and shapes, for specific teeth.

They can be categorized into:

- Posterior (Fig. 6.11)
- Anterior (Fig. 6.12)
- Winged
- Wingless (Fig. 6.13)

Advantages of wingless clamps: The fit of the clamp with the tooth can be better verified as in this technique clamp is placed prior to the rubber dam.

- Also better for the placement of matrix band.

Rubber dam template (Fig. 6.14): Matrix provided to mark the location where the rubber dam has to be punched.

Fig. 6.10: Rubber dam clamp holder

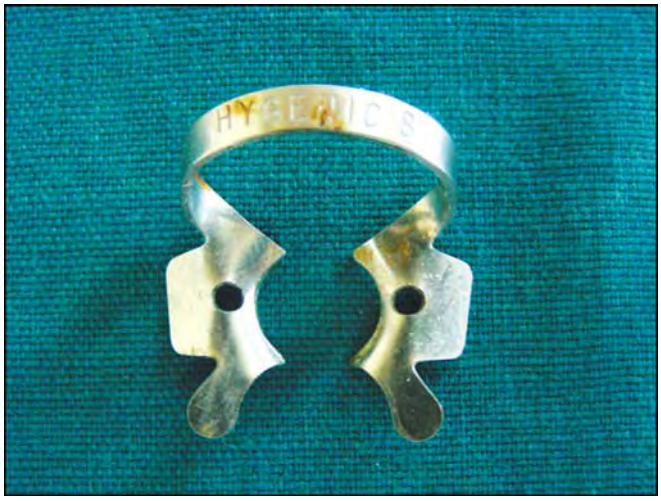


Fig. 6.11: Posterior clamp

Fig. 6.12: Anterior clamp

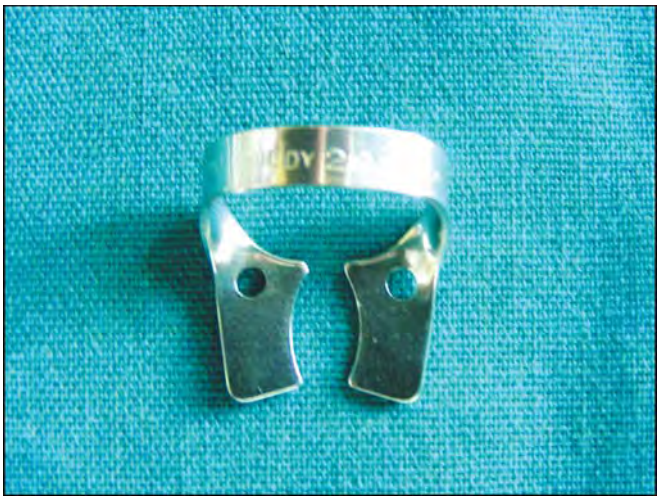


Fig. 6.13: Wingless clamp (W8A)

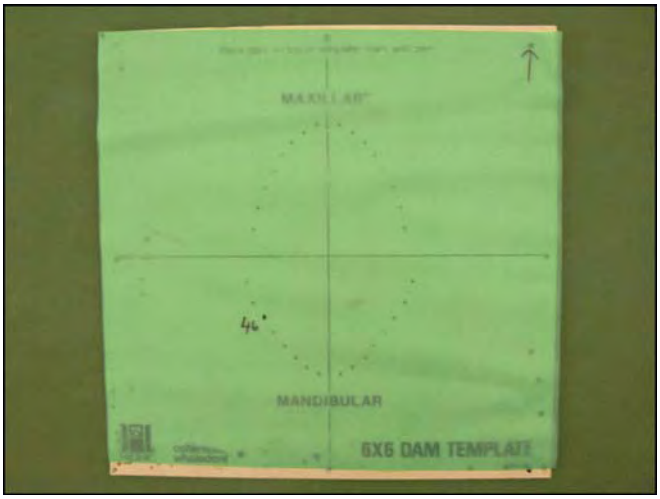


Fig. 6.14: Rubber dam template 6" x 6"

Application Technique (Figs 6.15 to 6.20)

The appropriate clamp for the tooth to be isolated is selected and tied with floss. The rubber dam is aligned and punched with the quadrant to be treated. The clamp, held with the forceps, is placed securely on the tooth. One advantage of this method is that the opportunity now exists to verify the fit of the clamp before dam placement. The rubber dam is now held in both hands, and the index fingers are used to stretch out the punched hole, which is slipped over the bow. of the clamp and pulled forward and down onto the tooth. The frame is applied, the floss removed and the seal verified or adjusted as necessary.

Difficult situations: Badly broken down teeth: Some cases require crown lengthening procedure, either by

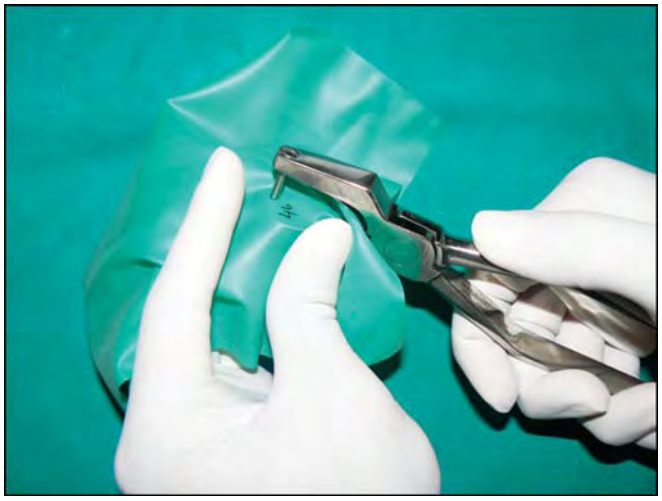


Fig. 6.15: Punching the sheet

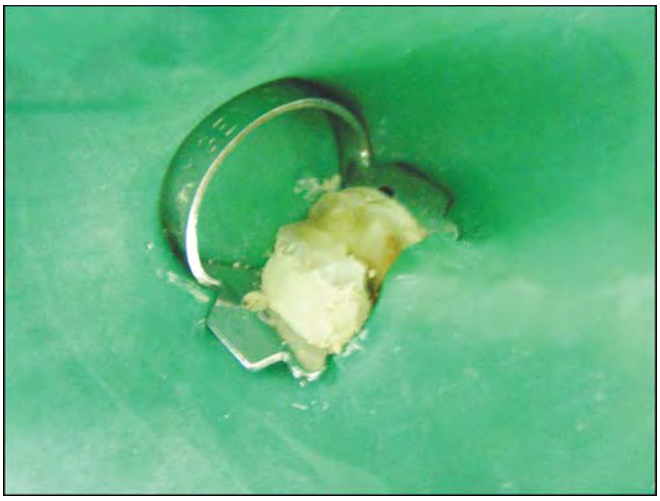


Fig. 6.18: Sealing with cavit to prevent leakage

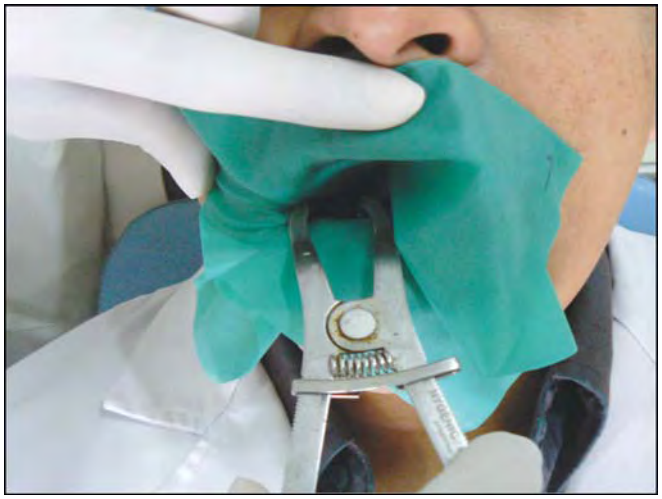


Fig. 6.16: Clamp loaded with clamp holder

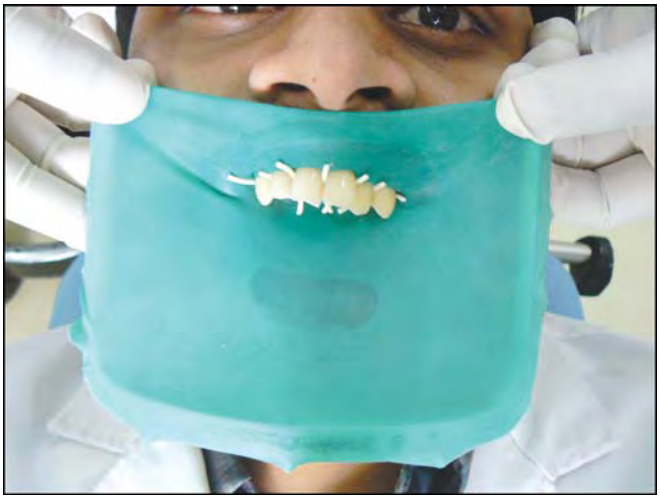


Fig. 6.19: Dam placed with interdental rubber (Wedjets)

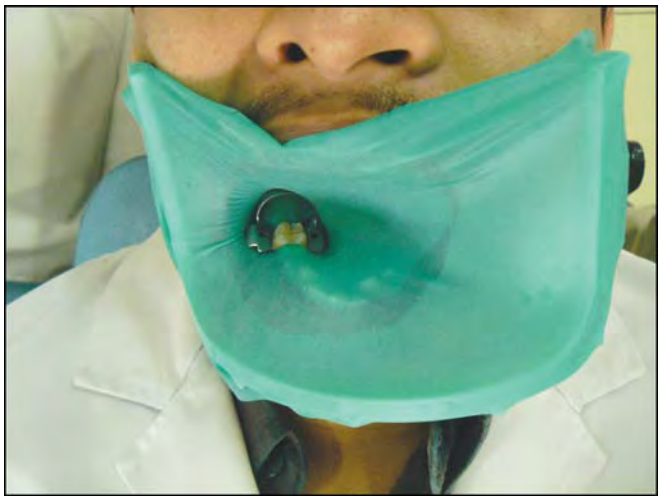


Fig. 6.17: Rubber dam in place

Fig. 6.20: Insta dam

gingivectomy or orthodontic extrusion or Composite donut technique prior to endodontic treatment.

For isolation in the area of bridges, split dam technique is used. A broken down tooth may also be isolated using a slit cut between the holes made for the two adjacent teeth. It is essential that Oraseal or Cavit is applied to prevent leakage and contamination.

STERILIZATION

It is a process by which an article surface or medium is freed of all microorganisms either in vegetative or spore state.

Disinfection

This is use of germicidal agents to destroy the potential infectivity of a material and need not imply elimination of all viable microbes.

- For maintenance of asepsis in surgeries
- Instruments and materials used in procedures
- Used in lab to keep the media, reagents and equipments sterile
- In food and drug manufacture.

Classification of Sterilization

I. Physical

1. Dry heat
   - Flaming
   - Incineration
   - Air
2. Moist heat
   - Boiling
   - Steam
   - Steam under high pressure
   - Healing at less temperature
3. Filtration
   - Candles
   - Membrane discs
   - Asbestos pads
4. Radiation
   a. Non-ionizing
      - UV rays
      - IR rays
   b. Ionizing rays
      - Gamma rays
      - High energy electrons
5. Gases:
   - Ethylene oxide
   - Formaldehyde
   - B - propionolactone

II. Chemical

1. Alcohol
   - Ethanol
   - Isopropanol
   - Trichlorobutanal
2. Aldehyde
   - Formaldehyde
   - Glutaraldehyde
3. Dyes
   - Aniline
   - Acridine compounds
4. Metallic salts
   - Mercurial
   - Silver
5. Phenols
   - Carlarlic acid
   - Cresole
   - Nylene
   - Chlorphenol
   - Bisphenol
6. Surface active agents
   - Anionic
   - Cationic
   - Non-ionic
   - Ampholytic compomer

Guidelines for ensuring proper sterilization:

- High quality sterilization equipment
- Well trained operator
- Weekly use of biological indicators to check the effectiveness of sterilization
- The instruments should be dried and cooled before removal from sterilizer.
- The sterilizer should be in a separate area and sterilized instrument should not come in contact with contaminated areas.

Classification of the instrument sterilization: Spaulding's classification for instruments.

1. *Critical items:* Instruments that enter the vascular system and those that penetrate the oral mucosa. E.g. Scapels, curettes, burs, files and dental handpieces.
2. *Semicritical items:* Instruments that touch mucous membranes but do not penetrate tissues. This includes amalgam condensers and saliva ejectors.

3. *Noncritical items:* Those items that do not come in contact with oral mucosa but are touchéd by saliva- or blood-contaminated hands while treating patients. Such items include light switches, counter-tops, and drawer pulls on cabinets.

Elements of a sterilization plan: [Modified from centers for disease control and prevention (CDC) guidelines for infection control in dental healthcare settings]

1. Transporting contaminated items from the operatory—items must be stored in a container to prevent perforation.
2. Instrument processing area-
   a. Instruments must be sorted, cleaned and rinsed with water in an area separate from sterilization.
   b. Instruments should be inspected, assembled into trays, and wrapped for sterilization in packages containing sterilization indicator.
   c. Instrument packages should be sterilized using approved methods.
   d. Instrument should be stored for event-related use.
3. Environmental infection control-
   a. Clinical contact surfaces (barrier protection, spray disinfectants)
   b. Dental unit waterlines
   c. Housekeeping surfaces
4. Nonregulated and regulated medical waste
5. Monitoring plan
6. Training plan

Heat

Heat is the most reliable method of sterilization and should be the method of choice unless contraindicated.

Fig. 6.21: Hot air oven

Moist heat is more effective than dry heat because it kills microorganism by coagulating and denaturing their enzymes and structural proteins, a process in which water precipitates.

A. Dry heat:

1. *Flaming:* Innoculating loops or wires, tips of forceps and searing spatulas are held in Bunsen burner till they become red hot in order to be sterilized.
2. *Incineration:* This is an excellent method for rapidly destroying materials such as soiled dressings, animal carcasses, bedding and pathogenic materials which are burnt to ash.
3. *Hot air oven (Fig. 6.21):*

- Dry heat, used properly, is an accepted and effective means of instrument sterilization and is safe for all dry metal instruments and mirrors.
- Moderate loads of bare instruments placed in an efficient oven at 160 to 170°C should be sterilized in an hour.
- If dry, all metal instruments (but not all handpieces) can be sterilized by dry heat without damage or rust at 160 to 168°C.
- Dry heat is acceptable for cloth goods and paper items. All burs appear to withstand dry heat sterilization well. Dry heat is not suitable for aqueous solutions, rubber goods, and most plastics.
- The time required for dry heat sterilization increases with the load size and wrapping of instrument packs, according to the ability of heat to reach all of the instruments.

Control of dry heat sterilization

– The spores of non-toxigenic strain of *Cl. tetani* are used as a microbiological test of dry heat efficiency
– Brown's tube (No 3 green spot).

B. Moist heat:

1. *Pasteurization:* The organism contributing to milk-borne disease such as *Brucella*, *Salmonella*, and Tubercle bacilli are readily killed by pasteurization. Two methods of pasteurization:
   A. Holder method—63°C for 30 mins
   B. Flash method—72°C for 15-20 mins.
2. *Boiling in water bath (100°C):* Vegetative bacteria are killed almost immediately at 90 to 100°C, but sporing bacteria require considerable period of boiling. Boiling is not recommended for sterilization of instruments used for surgical procedures.

Fig. 6.22: Autoclave

Fig. 6.23: Chemiclave

3. *Steam Under Pressure (Autoclave) (Fig. 6.22):* Most common method of sterilization of instruments in dentistry.

- *Principle of autoclave:* The principle of autoclave sterilizer is that water boils when its vapor pressure equals that of the surrounding atmosphere. Hence when the pressure inside a closed vessel increases, the temperature at which water boils also increases. Saturated steam has greater penetrating power, is non-toxic, non-corrosive and highly effective sterilizing agent.
  Materials that are sterilized in autoclave: High quality steel instruments, some of the burs, pluggers and condensers, glass slabs, dappen dishes, stainless steel surgical instruments, impression trays, rubber dam metal frames, etc. can be sterilized without damage. Carbon steel and low quality stainless steel instrument can rust and corrode unless carefully protected which can be done by dipping the instrument in a bath of 1 percent sodium nitrite before sterilization. Amine compounds can also be used.
- Temperature and time
  - 121°C for 15 mins at 15 lb
  - 134°C for 3 mins at 30 lb (Flash sterilization)

  For lightly wrapped instruments, five minutes should be added to both periods. For heavily wrapped, well separated surgical packs, the autoclave should be used for 20 mins at 121°C or for seven mins at 134°C.
- Disadvantage of autoclave- includes rusting, corroding, and dulling of instruments. Certain plastics and rubber are also sensitive to heat and moisture and cannot be placed in the autoclave.

4. *Chemiclave (chemical vapor sterilization) (Fig. 6.23)*

- Chemiclave uses a solution of 72 percent ethanol and 0.23 percent formaldehyde in place of water in its autoclave. The temperature requirements are 132°C for 20 mins at 20 lb.
- The chemicals include alcohol, acetone, ketones, and formaldehyde. The water content is below 15 percent level, above which rust, corrosion, and dullness of the metal occurs.

Advantages: Relatively short total cycle of approximately 25 minutes at sterilization temperature: no rusting of the instruments or charring of fabrics; and dry instruments at the end of the cycle.

Disadvantage is the odor that is released when the chemicals are heated. This method has become the popular mode of sterilization in endodontic offices.

Sterilization Control

For determining the efficiency of the moist-heat sterilization, spores of Bacillus stearothermophilus are used as the test organism.

Chemical indicators, autoclave tapes and thermocouples are also used instead.

Ethylene Oxide Sterilizer

- Exposure to ethylene oxide gas is an effective means of sterilizing delicate infrequently used items or contaminated items that are sensitive to heat. Accessible surfaces of almost any material or

instrument, including handpiece can be sterilized by ethylene oxide.
- A cycle of three to 12 hours is required for recycling routine instrument in frequent use.
- *Disadvantages:*
  1. Too long sterilization cycle.
  2. It is necessary to aerate plastic, rubber and other items to allow gas to escape completely otherwise chances of skin injuries are more.
  3. Ethylene oxide has difficulty in penetrating less accessible areas of complex instruments and cannot be expected to penetrate closed gas or metal containers.

Cold Chemical Sterilization

- Cold sterilization of the instruments that is, sterilization by cold chemical solution
- Heat sensitive critical and semi-critical instruments and devices can be sterilized by immersing them in a liquid chemical germicides registered by FDA as sterilants.
- Sporicidal chemicals (e.g. glutaraldehyde, peracidic acid and hydrogen peroxide) are highly toxic.
- Quaternary-ammonium compounds are effective against vegetative organisms; ethyl alcohol and isopropyl alcohol are effective against vegetative bacteria and tubercle bacilli and spores.
- Chlorine compounds, Iodophors, Phenolic compounds and Cleaning agents and surfactants can also be used.

Chlorine Compounds

- Sodium hypochlorite in 0.05 to 0.5 percent concentrations is recommended for surface, material and instrument disinfection. A contact time of 10 mins at 20°C is required for proper disinfection.Used for the disinfection of gutta-percha points.

Advantages

Immersion and environmental sterilant
1. Rapid action: 3 minutes for disinfection and 6 hours for the sterilization
2. Effective in dilution
3. Broad spectrum
4. Economical.

Disadvantages

1. Sporicidal only at high concentration
2. No reuse, daily preparation
3. Poor organic debris penetration
4. Eyewear, gloves required and adequate ventilation is required
5. Unpleasant odor, irritates skin, and eyes.
6. Corrodes metal, degrades plastics and rubber.

Other Surface Disinfectants

- Iodophors
- Phenolic compounds
- Cleaning agents and surfactants

Hot-salt Sterilizer

- This type of sterilizer is indispensable for endodontic work. It consists of a metal cup in which table salt is kept at a temperature of between 425°F (218°C) and 475°F (246°C), although a slightly higher temperature is not critical and does not impair the temper of the root canal instrument. A suitable thermometer should be inserted in the salt at all the times, so the temperature can be checked at a glance.
- At this temperature, root canal instruments such as broaches, files, and reamers can be sterilized in 5 seconds and cotton pellets in 10 seconds.
- To the usual commercial table salt, a small amount (1%) of sodium silicoaluminate, magnesium carbonate, or sodium carbonate should be added, so it pours readily and will not become fused under heat.
- Pure sodium chloride should not be used without the previously mentioned additives because high heat may cause fusion of the granules, nor the salt should contain dextrose as an additive because it may coalesce the granules of salt at high heat.
- The salt should be changed weekly or more often, depending on the degree of humidity.
- The hottest part of the salt sterilizer is along its outer rim, starting at the bottom layer of the salt; the temperature is lowest in the center of the surface layer of salt.
- To sterilize an instrument properly, one should immerse it at atleast a quarter-inch below the salt's surface and in the peripheral area of the sterilizer.

Fig. 6.24: Glass-bead sterilizer

- The advantage of the hot-salt sterilizer lies in the use of common salt which is readily available. Any salt accidentally carried into the root canal can easily be irrigated from the canal using the usual irrigating solutions.

Glass-bead Sterilizer (Fig. 6.24)

- An effective substitution for the hot-salt sterilizer provided the beads are less than 1 mm in diameter. Larger beads are not so effective in transferring heat to endodontic instruments, according to tests carried out by Oliet, because of the large air spaces between the beads that reduce the efficiency of the sterilizer.
- The glass bead sterilizer is operated at approximately the same temperature as that of the hot-salt sterilizer, i.e. between 218 and 246°C.
- Oliet showed that a slightly higher temperature is reached with salt than with glass bead at the same temperature setting of the thermostat, probably because the salt granules are smaller than glass beads, the air space between granules is thus reduced and the conductivity of heat by the salt is higher.
- The other aspects of the glass-bead sterilizer are same as that of the hot-salt sterilizer.

Sterilization by Radiation

Two types of radiation are used for sterilizing purposes: nonionising and ionizing. Infrared and ultraviolet rays are of nonionizing low energy type, while gamma rays and high energy electrons are of high energy ionizing type.

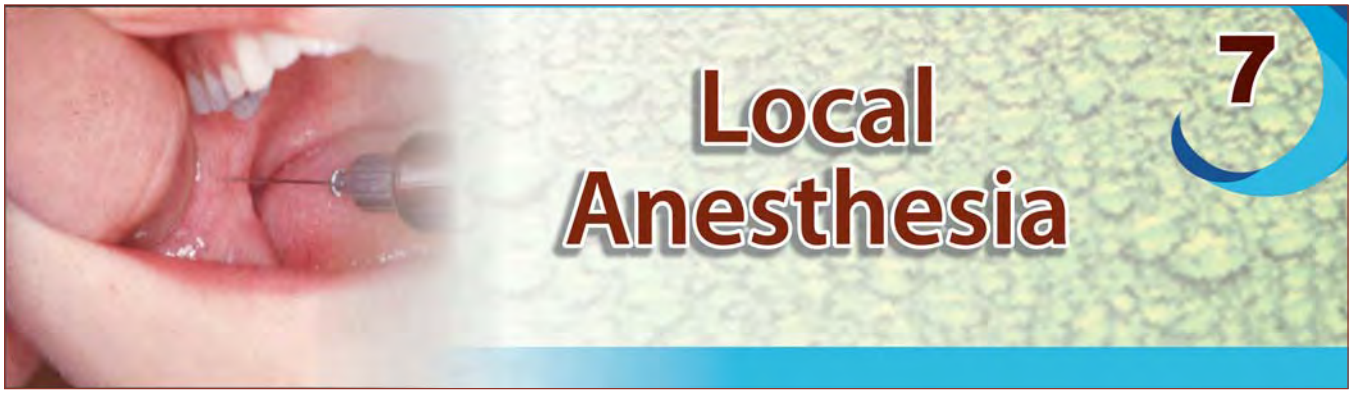
1. Non-ionizing radiation- non-particulate, consisting of rays with wavelength shorter or longer than those of visible light and to a large extent are absorbed as heat.
   a. Infrared radiation
   b. Ultraviolet radiation
2. *Ionizing radiation:* The ionizing radiation may be:
   a. Particulate
   b. Electromagnetic.

SUGGESTED READING

1. Bender IB, Seltzer S, Yermish M. The incidence of bacteremia in endodontic manipulation. Oral Surg 1960;13:353.
2. Bibel D. The discovery of the oral flora: a 300-year retrospective. J Am Dent Assoc 1983;107:569.
3. Baumgartner JC, Heggers J, Harrison J. The incidence of bacteremias related to endodontic procedures. I. Nonsurgical endodontics. JOE 1976;2:135.
4. Baumgartner JC, Heggers JP, Harrison JW. Incidence of bacteremias related to endodontic procedures. II. Surgical endodontics. JOE 1977;3:399.
5. Bergenholtz G, Lindhe J. Effect of soluble plaque factors on inflammatory reactions in the dental pulp. Scand J Dent Res 1975;83:153.
6. Baumgartner JC, Falkler WA Jr. Bacteria in the apical 5 mm of infected root canals. JOE 1991;17:380.
7. Byström A, Happonen RP, Sjögren U, Sundqvist G. Healing of periapical lesions of pulpless teeth after endodontic treatment with controlled asepsis. Endod Dent Traumatol 1987;3:58.
8. Brook I, Frazier E. Clinical features and aerobic and anaerobic microbiological characteristics of cellulitis. Arch Surg 1995;130:786.
9. Brook I, Frazier E, Gher MJ. Microbiology of periapical abscesses and associated maxillary sinusitis. J Periodontol 1996;67:608.
10. Bystrom A, Sundqvist G. Bacteriologic evaluation of the efficacy of mechanical root canal instrumentation in endodontic therapy. Scand J Dent Res 1981;89:321.
11. Bystrom A, Sundqvist G. Bacteriologic evaluation of the effectof 0.5 percent sodium hypochlorite in endodontic therapy. Oral Surg 1983;55:307.
12. Bystrom A, Sundqvist G. The antibacterial action of sodium hypochlorite and EDTA in 60 cases of endodontic therapy. Int Endod J 1985;1:35.
13. Cvek M, Cleaton-Jones PE, Austin JC, Andreason JO. Pulp reactions to exposure after experimental crown fractures or grinding in adult monkeys. JOE 1982;8:391.
14. Czarnecki RT, Schilder H. A histological evaluation of the human pulp in teeth with varying degrees of periodontal disease. JOE 1979;5:242.

15. Debelian GF, Olsen I, Tronstad L. Bacteremia in conjunction with endodontic therapy. Endod Dent Traumatol 1995;11:142.
16. DeStefano F, Anda R, Kahn H, et al. Dental disease and risk of coronary heart disease and mortality. Br Dent J 1993;306:688.
17. Debelian GJ,Olsen I,Tronstad L. Bacteremia in conjunction with endodontic therapy. Endod Dent Traumatol 1995;11:142.
18. Dwyer TG, Torabinejad M. Radiographic and histologic evaluation of the effect of endotoxin on the periapical tissues of the cat. JOE 1981;7:31.
19. Drucker D, Lilley J, Tucker D, Gibbs C. The endodontic microflora revisited. Microbios 1992;71:225.
20. Easlick K.An evaluation of the effect of dental foci of infection on health. J Am Dent Assoc 1951;42:694.
21. Eftimiadi C, Stashenko P, Tonetti M, et al. Divergent effect of the anaerobic bacteria by-product butyric acid on the immune response: suppression of T-lymphocyte proliferation and stimulation of interleukin-1 beta production. Oral Microbiol Immunol 1991;6:17.
22. Fish EW. Bone infection. J Am Dent Assoc 1939;26:691.
23. Fabricius L, Dahlén G, Öhman AE, Möller ÅJR. Predominant indigenous oral bacteria isolated from infected root canals after varied times of closure. Scand J Dent Res 1982;90:134.
24. Fabricius L, Dahlén G, Holm SE, Möller ÅJR. Influence of combinations of oral bacteria on periapical tissues of monkeys. Scand J Dent Res 1982;90:200.
25. Gier RE,Mitchell DF. Anachoretic effect of pulpitis. J Dent Res 1968;47:564.
26. Glick M, Trope M, Pliskin M. Detection of HIV in the dental pulp of a patient with AIDS. J Am Dent Assoc 1989; 119:649.
27. Glick M, Trope M, Pliskin E. Human immunodeficiency virus infection of fibroblasts of dental pulp in seropositive patients. Oral Surg 1991;71:733.
28. Grossman LI. Focal infection: are oral foci of infection related to systemic disease? Dent Clin North Am 1960;4:749.
29. Gomes B, Drucker D, Lilley J. Positive and negative associations between bacterial species in dental root canals. Microbios 1994;80:231.
30. Gomes BPFA, Drucker DB, Lilley JD. Association of specific bacteria with some endodontic signs and symptoms. Int Endod J 1994;27:291.
31. Gomes B, Lilley J, Drucker D. Clinical significance of dental root canal microflora. J Dent 1996;24:47.
32. Griffee MB, Patterson SS, Miller CH, et al. The relationship of Bacteroides melaninogenicus to symptoms associated with pulpal necrosis. Oral Surg 1980;50:457.
33. Heimdahl A, Hall G, Hedberg M, Sandberg H. Detection and quantitation by lysis-filtration of bacteremia after different oral surgical procedures. J Clin Microbiol 1990;28:2205.
34. Happonen RP. Periapical actinomycosis: a follow-up study of 16 surgically treated cases. Endod Dent Traumatol 1986;2:205.
35. Heimdahl A,Von Konow L, Satoh T,Nord CE. Clinical appearance of orofacial infections of odontogenic origin in relation to microbiological findings. J Clin Microbiol 1985;22:299.
36. Hashioka K, Yamasaki M, Nakane A, et al. The relationship between clinical symptoms and anaerobic bacteria from infected root canals. JOE 1992;18:558.
37. Horiba N,Maekawa Y,Abe Y, et al. Correlations between endotoxin and clinical symptoms or radiolucent areas in infected root canals. Oral Surg 1991;71:492.
38. Horiba N, Maekawa Y, Yamauchi Y, et al. Complement activation by lipopolysaccharides purified from gram-negative bacteria isolated from infected root canals. Oral Surg 1992;74:648.
39. Haapasalo M, Ranta H, Rantah K, Shah H. Black-pigmented Bacteroides spp. in human apical periodontitis. Infect Immun 1986;53:149.
40. Haapasalo M. Bacteroides spp. in dental root canal infections. Endod Dent Traumatol 1989;5:1.
41. Kinder SA, Holt SC. Characterization of coaggregation between Bacteroides gingivalis T22 and Fusobacterium nucleatum T18. Infect Immun 1989;57:3425.
42. Kakehashi S, Stanley HR, Fitzgerald RJ. The effects of surgical exposures of dental pulps in germ-free and conventional laboratory rats. Oral Surg 1965;20:340.
43. Kobayashi T,Hayashi A,Yoshikawa R, et al. The microbial flora from root canals and periodontal pockets of non-vital teeth associated with advanced periodontitis. Int Endod J 1990;23:100.
44. Langeland K. Tissue changes in the dental pulp. Odontol Tidskr 1957;65:239.
45. Langeland K, Rodrigues H, Dowden W. Periodontal disease, bacteria, and pulpal histopathology. Oral Surg 1974;37:257.
46. Marshall K. Dental workspace contamination and the role of rubber dam. CPD Dentistry 2001; 2: 48-50.
47. Maita E,Horiuchi H. Polyamine analysis of infected root canal contents related to clinical symptoms. Endod Dent Traumatol 1990;6:213.
48. Moller AJR. Influence on periapical tissues of indigenous oral bacteria and necrotic pulp tissue in monkeys. Scand J Dent Res 1981;89:475.
49. Miller WD. An introduction in the study of the bacteriopathology of the dental pulp. Dent Cosmos 1894;36:505.
50. Meinig G. Root canal cover-up exposed. Ojai (CA): Bion Publishing; 1993.
51. Mazur B, Massler M. Influence of periodontal disease on the dental pulp. Oral Surg 1964;17:592.
52. Nair PNR, Sjogren U, Krey G, et al. Intraradicular bacteria and fungi in root-filled, asymptomatic human teeth with therapy- resistant periapical lesions: a long-term light and electron microscopic follow-up study. JOE 1990;16:580.
53. Offenbacher S, Katz V, Fertik G, et al. Periodontal infection as a risk factor for preterm low birth weight. J Periodont 1996;67:1103.

54. Odell EL. Zinc as a growth factor for Aspergillus sp. and the antifungal effects of root canal sealants. Oral Surg 1995;79:82.
55. Sen B, Safavi K, Spangberg L. Growth patterns of candida albicans in relation to radicular dentin. Oral Surg 1997;84:68.
56. Sundqvist G, Bloom GD, Enberg K, Johansson E. Phagocytosis of Bacteroides melaninogenicus and Bacteroides gingivalis in vitro by human neutrophils. J Periodontal Res 1982;17:113.
57. Sundqvist GK, Carlsson J, Herrmann B, et al. Degradation in vivo of the C3 protein of guinea-pig complement by a pathogenic strain of Bacteroides gingivalis. Scand J Dent Res 1984;92:14. 88 Endodontics
58. Sundqvist G, Carlsson J, Herrmann B, Tärnvik A. Degradation of human immunoglobulins G and M and complement factors C3 and C5 by black-pigmented Bacteroides. J Med Microbiol 1985;19:85.
59. Sundqvist G, Carlsson J, Hånström L. Collagenolytic activity of black-pigmented Bacteroides species. J Periodontal Res 1987;22:300.
60. Shah HH. Biology of the species Porphyromonas gingivalis. Ann Arbor (MI): CRC Press; 1993.
61. Sundqvist GK. Bacteriological studies of necrotic dental pulps [dissertation]. Umea (Sweden): Univ. Umea; 1976.
62. Sundqvist G, Johansson E, Sjögren U. Prevalence of black-pigmented Bacteroides species in root canal infections. JOE 1989;15:13.
63. Sundqvist G. Associations between microbial species in dental root canal infections. Oral Microbiol Immunol 1992;7:257.
64. Sjögren U, Figdor D, Persson S, Sundqvist G. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. Int Endod J 1997 Sep;30(5):297-306
65. Torabinejad M, Kiger RD. A histologic evaluation of dental pulp tissue of a patient with periodontal disease. Oral Surg 1985;59:198.
66. Trope M, Rosenberg E, Tronstad L. Darkfield microscopic spirochete count in the differentiation of endodontic and periodontal abscesses. JOE 1992;18:82.
67. Van Winkelhoff AJ, Carlee AW, de Graaff J. Bacteroides endodontalis and other black-pigmented Bacteroides species in odontogenic abscesses. Infect Immun 1985;49:494.
68. Warfvinge J, Bergenholtz G. Healing capacity of human and monkey dental pulps following experimentally-induced pulpitis. Endod Dent Traumatol 1986;2:256.
69. Wong R, Hirsch RS, Clarke NG. Endodontic effects of root planing in humans. Endod Dent Traumatol 1989;5:193.
70. Yoshida M, Fukushima H, Yamamoto K, et al. Correlation between clinical symptoms and microorganisms isolated from root canals of teeth with periapical pathosis. JOE 1987;13:24.



7 Local Anesthesia

A local anesthetic is a drug that reversibly inhibits the propagation of signals along nerves. When it is used on specific nerve pathways, effects such as analgesia (loss of pain sensation) and paralysis (loss of muscle power) can be achieved.

EARLY LOCAL ANESTHETICS

The first effective local anesthetic was cocaine. Isolated in 1859, it was first used by Karl Koller, at the suggestion of Sigmund Freud, in ophthalmic surgery in 1884. Before that doctors had used a salt and ice mix for the numbing effects of cold, which could only have limited application. Similar numbing was also induced by a spray of ether or ethyl chloride. A number of cocaine derivatives and safer replacements were soon produced, including procaine (1905), Eucaine (1900), Stovaine (1904), and lidocaine (1943).

Opioids were first used by Racoviceanu-Pitesti, who reported his work in 1901.

Synthetic local anesthetics are structurally related to cocaine. They differ from cocaine mainly in that they have no abuse potential and do not act on the sympathoadrenergic system, i.e. they do not produce hypertension or local vasoconstriction.

Selection of local anesthesia depends on several factors:

- Duration of the procedure being carried out
- Type of the procedure
- Any systemic diseases
- Pulpal and periradicular diagnosis.

Classification

Local anesthetics are broadly classified as esters and amides. Esters are not being used nowadays as they have side effects and greater tendency for allergic reactions.

- Amino esters
  - Benzocaine
  - Chloroprocaine
  - Cocaine
  - Procaine
  - Tetracaine
- Amino amides
  - Bupivacaine
  - Levobupivacaine
  - Lidocaine
  - Mepivacaine
  - Prilocaine
  - Ropivacaine
  - Articaine
  - Trimecaine
- Combinations
  - Lidocaine/prilocaine (EMLA)

Local anesthetics vary in their pharmacological properties and they are used in various techniques of local anesthesia such as:

- Topical anesthesia (surface)
- Infiltration
- Field block
- Intraligamentary
- Intraosseous
- Intrapulpal
- Nerve blocks

Surface anesthesia: Application of local anesthetic spray, solution or cream to the skin or a mucous membrane. The effect is short lasting and is limited to the area of contact.

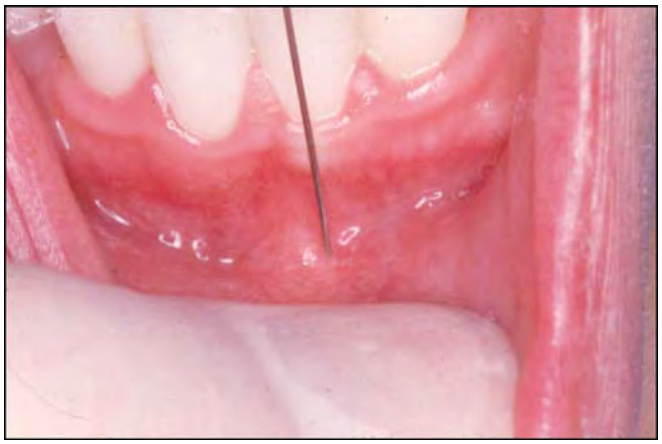


Fig. 7.1: Infiltration anesthesia

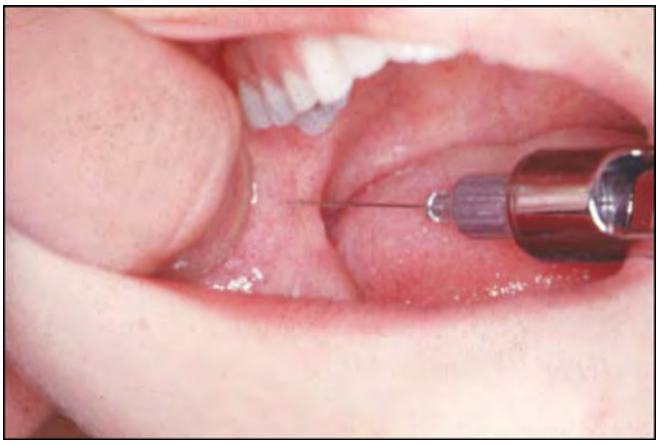


Fig. 7.3: Inferior alveolar nerve block

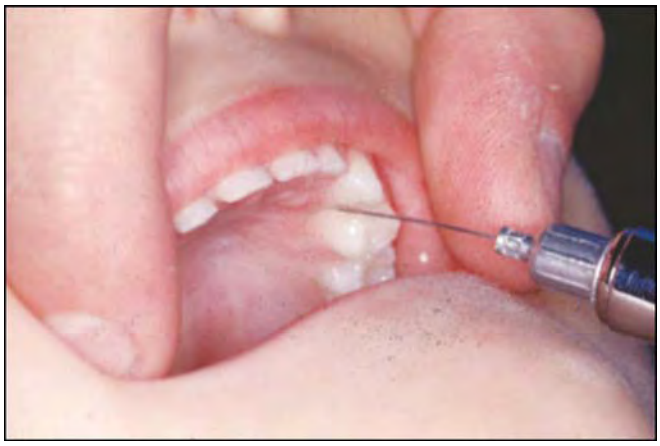


Fig. 7.2: Intraligamentary anesthesia

Infiltration anesthesia: Superficial injection of local anesthetic into the tissue to be anesthetized (Fig. 7.1).

Field block: Subcutaneous injection of a local anesthetic in an area bordering on the field to be anesthetized.

Intraligamentary anesthesia: Injection of the local anesthetic to the periodontal ligament (Fig. 7.2).

Intrapulpal anesthesia: Injection of the local anesthetic into the pulp cavity.

Nerve Blocks: Injection of local anesthetic in the vicinity of a peripheral nerve to anesthetize that nerve's area of innervation (Fig. 7.3).

Vasoconstrictors in LA

Improve quality of pain control and decrease the potential toxicity of the LA.

Functions

- Constrict vessels and decrease blood flow to the site of injection.
- Absorption of LA into bloodstream is slowed, producing lower levels in the blood.
- Lower blood levels lead to decreased risk of overdose (toxic) reaction.
- Higher LA concentration remains around the nerve increasing the LA's duration of action.
- Minimize bleeding at the site of administration.

Available Products

- Epinephrine
- Norepinephrine
- Levonordefrin (neocobefrine): Side effects and overdose same as epinephrine but to a lesser extent. One-sixth as effective as epinephrine as a vasopressor so used in 1/20,000 concentration.

Mechanism of Action

Local anesthetics exhibit both charged and uncharged forms. Charged form is cation which has positive charge. Uncharged form is anion which has the negative charge. Ratio of these cations to anions depends on pH of the both local anesthetic and soft tissue and pKa of the anesthetic. Anionic uncharged form passes through the nerve membrane because of its lipid solubility. Once it enters the nerve fiber, the anion dissociates again and the newly dissociated cations bind to the sodium channels. This prevents the inflow of sodium ions thus resulting in blockade

of neuronal depolarization. As a result, the transfer of signals from the peripheral tissues to the central nervous system is blocked. In the areas of inflammation and pus discharge, local anesthetic will not work effectively. This is because of less number of anions to penetrate the nerve membrane and later, less dissociation into cations within the nerve. Most of the anesthetics used in clinical practice will have an onset of action between 1 and 20 minutes.

NOMENCLATURE OF LOCAL ANESTHETICS

Depending on the duration of action, local anesthetics are classified as:

Short Duration Local Anesthetics (Less than 60 mins)

Example: 2 percent Lidocaine, 3 percent Mepivacaine, 4 percent Prilocaine.

Moderate Duration Local Anesthetics (60-120 mins)

- 2 percent Lidocaine with adrenaline 1:50,000 or 1:100000
- 2 percent Mepivacaine with 1:20000 Levonordefrin
- 4 percent prilocaine with 1:200000 adrenaline
- 4 percent articaine hydrochloride with1:100,000 adrenaline.

Long Duration Local Anesthetics (More than 120 mins)

- 0.5 percent Bupivacaine with 1:200000 adrenaline
- 1.5 percent Etidocaine with 1:200000 adrenaline

COMMONLY USED LOCAL ANESTHETICS

Two Percent Lidocaine with Adrenaline 1:50,000 or 1:100,000

This is an anesthetic most commonly used for endodontic dental procedures. This is a amide type of local anesthetic. The molecule belongs to xylidine group. Available as the carpules of 1.8 ml dental anesthetic carpules and vials of 30 ml Each carpule contains 36 mg of local anesthetic. The regular adult dose is 0.9-3.6 ml and the maximum dose is 8 carpules. 2 percent lignocaine with 1:50000 is used for local infiltration in the tissues renders excellent hemostasis at the surgical site. Detoxification of this drug primarily occurs in the liver. So, it should be used with caution in patients with severe liver disease. It should not be used in patients using MAO inhibitors and tricycles antidepressants. It is not contraindicated in pregnant women (after 1st trimester) or nursing mothers.

Three Percent Mepivacaine with Levonordefrin 1:20000

- Amide-type of local anesthetic
- Derivative of xylidine

Available in 1.8 mL dental anesthetic carpules (each carpule of 3 percent Mepivacaine contains 54 mg of anesthetic). Usual dosage in adults is 1.8-9 mL (maximum of 5 carpules of 3%). Three percent Mepivacaine without vasoconstrictor is not indicated for routine endodontic procedures, as duration is usually too short. High blood level concentrations of Mepivacaine may result in CNS disturbances (e.g. anxiety, dizziness, tremors, confusion). Have approximately same toxicity levels as xylocaine. Because of levonordefrin content, should not routinely be used in patients on MAO inhibitors or tricyclic antidepressants.

Four Percent Prilocaine (Plain 4%) and 4 Percent Prilocaine with 1:200,000 Adrenaline

- Amide-type of local anesthetic
- Derivative of toluidine

Available in 1.8 mL dental anesthetic carpules (each carpule contains 72 mg of anesthetic). Usual dosage in adults is 1.8-5.4 mL. Maximum dose should not exceed 5 carpules. Because of epinephrine content (Prilocaine w/1;200000 epi), should not routinely be used in patients on MAO inhibitors or tricyclic antidepressants.

High blood level concentrations of Prilocaine may result in CNS disturbances (e.g. anxiety, dizziness, tremors, confusion).

0.5 Percent Bupivacaine w/1.200,000 Adrenaline

- Amide-type of locai anesthetic
- Derivative of xylidine

Available in 1.8 mL dental anesthetic carpules (each carpule contains 9 mg of anesthetic). Maximum dosage is 10 carpules or about 90 mg of anesthetic. Generally 2-3 times longer duration than xylocaine.

May provide anesthesia for 10-12 hours; however, usually a 5- to 7-hour range is normal. Used generally as a local anesthetic for surgical procedures in endodontics and oral surgery because of the extended duration. Because of epinephrine content (Bupivacaine w/1.200,000 epi), should not be used routinely in patients on MAO inhibitors or tricyclic antidepressants. High blood level concentrations of Bupivacaine may result in CNS disturbances (e.g. anxiety, dizziness, tremors, confusion).

1.5 Percent Etidocaine with 1:200,000 Adrenaline

- Amide-type of local anesthetic
- Derivative of xylidine

Available in 1.8 mL dental anesthetic carpules (each carpule contains 27 mg of anesthetic). Usual dose is 1-2 carpules with a maximum adult dosage of adult dosage is 8 carpules.

May provide anesthesia for 8-12 hours; however, usually a 5- to 8-hour range is normal. Used generally as a local anesthetic for surgical procedures in endodontics and oral surgery because of the extended duration. Because of epinephrine content (Etidocaine w/1:200,000 epi), should not routinely be used in patients on MAO inhibitors or tricyclic antidepressants. High blood level concentrations of Etidocaine may result in CNS disturbances (e.g. anxiety, dizziness, tremors, confusion).

Articaine Hydrochloride w/1:100,000 Adrenaline

First FDA-approved anesthetic in 30 years to provide complete pulpal anesthesia Contains both amide and ester linkage; chemically unique. Available in 1.7 mL dental anesthetic carpules (each contains 68 mg or articaine hydrochloride 4%). Usual dose is 0.7-3.4 mL or 0.5-2 carpules. Provides profound anesthesia in 1 hour Elimination half-life is 1.8 hours. Metabolism is hepatic by plasma carboxyesterase to articainic acid drug interactions with MAO inhibitors, Phenothiazines, tricyclic antidepressants.

Undesired Effects

The conduction of electric impulses follows a similar mechanism in peripheral nerves, the central nervous system, and the heart. The effects of local anesthetics are therefore not specific for the signal conduction in peripheral nerves. Side effects on the central nervous system and the heart may be severe and potentially fatal. However, toxicity usually occurs only at blood plasma levels which are rarely reached if proper anesthetic techniques are adhered.

Central Nervous System

Depending on local tissue concentrations of local anesthetics, there may be excitatory or depressant effects on the central nervous system. At lower concentrations, a relatively selective depression of inhibitory neurons results in cerebral excitation, which may lead to generalized convulsions. A profound depression of brain functions occurs at higher concentrations which may lead to coma, respiratory arrest and death. Such tissue concentrations may be due to very high plasma levels after intravenous injection of a large dose. Another possibility is direct exposure of the central nervous system through the CSF, i.e. overdose in spinal anesthesia or accidental injection into the subarachnoid space in epidural anesthesia.

Cardiovascular System

The conductive system of the heart is quite sensitive to the action of local anesthetics. Lidocaine is often used as an antiarrhythmic drug and has been studied extensively, but the effects of other local anesthetics are probably similar to those of Lidocaine. Lidocaine acts by blocking sodium channels, leading to slowed conduction of impulses. This may obviously result in bradycardia, but tachyarrhythmia can also occur. With high plasma levels of lidocaine there may be higher-degree atrioventricular block and severe bradycardia, leading to coma and possibly death.

Treatment of Overdose: "Lipid Rescue"

There is evidence that intralipid, a commonly available intravenous lipid emulsion, can be effective in treating severe cardiotoxicity secondary to local anesthetic overdose, including human case reports of successful use in this way (“lipid rescue”).

Hypersensitivity/Allergy

Adverse reactions to local anesthetics are not infrequent, but true allergy is very rare. Non-allergic

reactions may resemble allergy in their manifestations. In some cases, skin tests and provocative challenge may be necessary to establish a diagnosis of allergy. There are also cases of allergy to paraben derivatives, which are often added as preservatives to local anesthetic solutions.

Methemoglobinemia

The systemic toxicity of prilocaine is comparatively low, however, its metabolite, *o*-toluidine, is known to cause methemoglobinemia. As methemoglobinemia reduces the amount of hemoglobin that is available for oxygen transport, this side effect is potentially life-threatening. Therefore, dose limits for prilocaine should be strictly observed. Prilocaine is not recommended for use in infants.

SUGGESTED READING

1. ADA Council on Dental Materials, Instruments, and Equipment. Status report: the periodontal ligament injection. J Am Dent Assoc 1983;106:222.
2. Akinosi JO. A new approach to the mandibular nerve block. Br J Oral Surg 1977;15:83.
3. Brannstrom M, Lindskog S, Nordenvall KJ. Enamel hypoplasia in permanent teeth induced by periodontal ligament anesthesia of primary teeth. J Am Dent Assoc 1984;109:735.
4. Gow-Gates GAE. Mandibular conduction anesthesia: a new technique using extraoral landmarks. Oral Surg 1973;36:321.
5. Jastak JT, Yagiela JA. Local anesthesia of the oral cavity. Philadelphia: WB Saunders; 1995.
6. Jofre J, Munzenmayer C. Design and preliminary evaluation of an extraoral Gow-Gates guiding device. Oral Surg 1998;85:661.
7. Loetscher CA, Melton DC, Walton RE. Injection regimen for anesthesia of the maxillary first molar. J Am Dent Assoc 1988;117:337.
8. Leonard M. The efficacy of an intraosseous injection system of delivering local anesthesia. J Am Dent Assoc 1995;126:81.
9. Leonard M. The Stabident System of intraosseous anesthesia.Dent Econ 1997;87:51.
10. Malamed SF. Handbook of local anesthesia. 4th ed. St. Louis (MO): Mosby; 1997.
11. Malamed SF, Weine F. Profound pulpal anesthesia Chicago: American Association of Endodontics; 1988.
12. Malamed SF. The Gow-Gates mandibular nerve block: evaluation after 4275 cases. Oral Surg 1981;51:463.
13. Malamed SF. The periodontal ligament (PDL) injection: an alternative to inferior alveolar nerve block. Oral Surg 1982;53:117.
14. Nustein J, Reader A, Nist R, et al. Anesthetic efficacy of the supplemental intraosseous injection of 2 percent lidocaine with 1:100,000 epinephrine in irreversible pulpitis. JOE 1998;24:487.
15. Parente SA, Anderson RW, Herman WW, et al. Anesthetic efficacy of the supplemental intraosseous injection for teeth with irreversible pulpitis. JOE 1998;24:826.
16. Vasirani SJ. Closed mouth mandibular nerve block: a new technique. Dent Dig 1960;66:10.

Pulp capping is a treatment where a protective agent is applied to an exposed pulp to allow the pulp to recover and maintain its vitality and function.

Or

Placement of a medicament, dressing or dental material over the pulp in an attempt to preserve its vitality.

A pulp exposure is defined as "the result of pathological changes in the hard tissue of a tooth caused by carious lesions, mechanical factors, or trauma, which render the pulp susceptible to bacterial invasion from the external environment". Ideally, the pulp exposure should be treated so that it will heal with new hard tissue forming a complete enclosure of the pulp. Hard tissue formation has been observed after different pulp capping procedures.

TYPES

- Direct pulp capping
- Indirect pulp capping

Direct Pulp Cap (Figs 8.1 and 8.2)

- *Definition:* The placement of a biocompatible agent (calcium hydroxide) on healthy pulp tissue that has been inadvertently exposed from caries excavation or traumatic injury.
- *Treatment objective:* To seal the pulp against bacterial leakage, stimulate the pulp to wall off the exposure site by initiating a dentin bridge, and maintain the vitality of the underlying pulp tissue.

Parameters for the Direct Pulp Cap

1. "Pinpoint" mechanical exposures less than 1sq mm surrounded by sound dentin,
2. Asymptomatic tooth.

Fig. 8.1: Operative procedure: Tooth with pulpal exposure

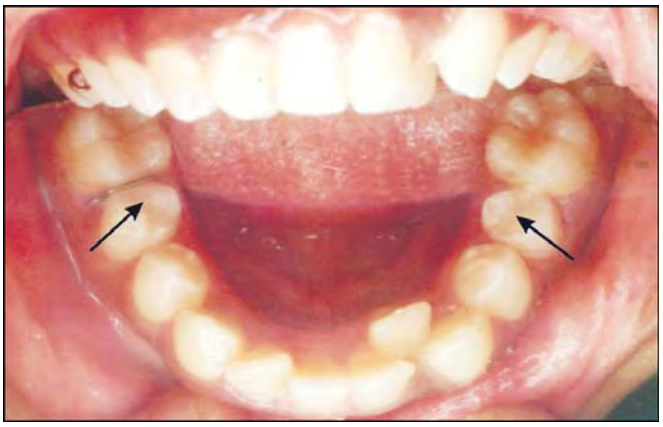


Fig. 8.2: Final restoration of the tooth with composite resin

Indirect Pulp Cap

Definition: The application of a medicament over a thin layer of remaining carious dentin, with no exposure of the pulp.

Can be done in primary and permanent teeth.

Treatment objective: To generate reparative dentin formation.

Rationale: There are three dentinal layers in a carious lesion:

1. A necrotic, soft, brown dentin outer layer, with bacteria;
2. A firmer, discolored dentin layer with fewer bacteria; and
3. A hard, discolored dentin deep layer with a minimal amount of bacterial invasion.

Clinical evaluation of pulp capping procedure depends on criteria such as sensitivity to electric pulp testing, radiological findings of apical pathology, pain and swelling. These criteria may not reflect the hard tissue formation or the status of the pulp.

Ideal Properties of Pulp Capping Material

- Sealing ability
- Biocompatibility
- Non-toxic
- Non-resorbable
- Radiopaque
- Bacteriostatic
- Ability to induce osteogenesis and cementogenesis.

Various materials have been implicated for use as pulp repair material such as calcium hydroxide; mineral trioxide aggregate, dentin bonding agents and resin modified glass ionomer cement, etc.

CALCIUM HYDROXIDE (HERMAN, 1920) (FIGS 8.3A TO D)

Traditionally, calcium hydroxide, by virtue of its dual properties of high alkalinity and antibacterial action, has been the most popular and successful pulp-capping agent.

- Calcium hydroxide with an alkaline pH of 11 to 12 is known to stimulate the activation of the alkaline phosphatase enzyme.
- Helps in the differentiation of undifferentiated mesenchymal cells of the pulp into odontoblast-like cells.
- With the dissolution of calcium hydroxide into calcium and hydroxyl ions, calcium ions have mitogenic potential to improve migration, differentiation and mineralization.
- Hydroxyl ions induce high level of alkalinity for the division of cells, to act against inflammation and to play a role in the formation of reparative dentinal bridge.

This makes calcium hydroxide a successful and predictable pulp-capping agent.

Functions when Used as Pulp Capping Agents

- Prevents postoperative sensitivity
- Reactionary or reparative dentin deposition.
- Sclerosis of the dentinal tubules
- Antimicrobial layer
- Odontoblastoid cell differentiation
- Dentin bridge formation.

Disadvantages

- Antimicrobial effect: Transient.
- Non-adhesive properties.
- Degradation over time.
- Tunneling defects through the bridge
- Poor sealing ability.

Histological Evaluation of Pulp after One Week

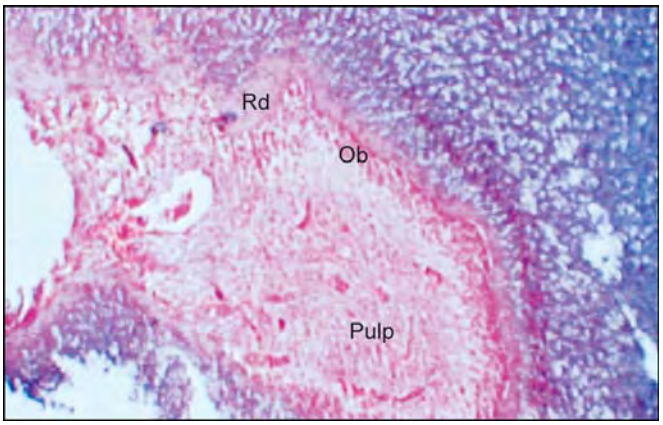


Fig. 8.3A: Calcium hydroxide + composite (10X)

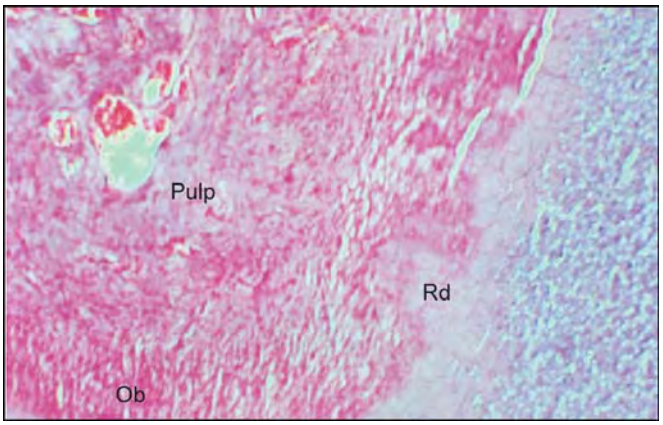


Fig. 8.3B: Calcium hydroxide + composite (25X)

Histological Evaluation of Pulp after Two Weeks

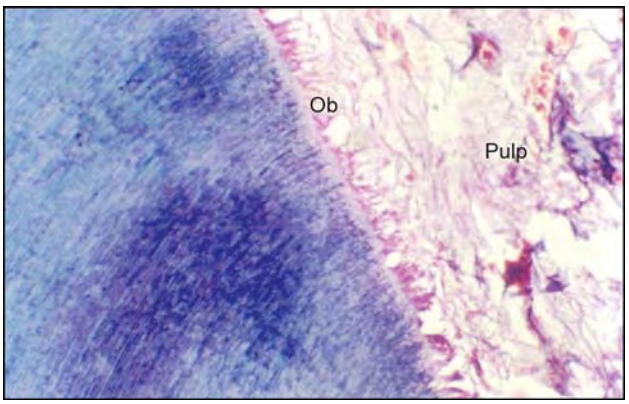


Fig. 8.3C: Calcium hydroxide + composite (10X)

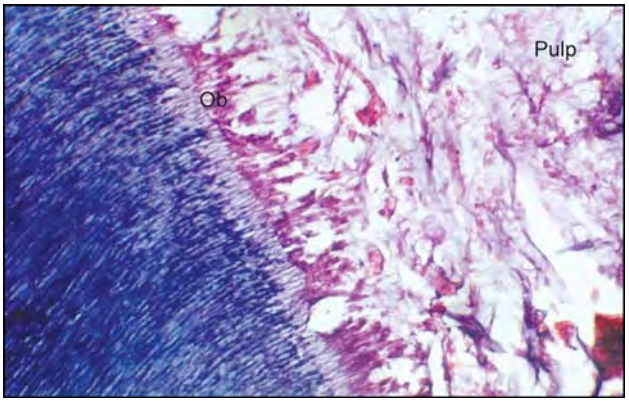


Fig. 8.3D: Calcium hydroxide + composite (25X)

DENTIN BONDING AGENTS (FIGS 8.3E TO H)

Dentin bonding agents (DBA) have been examined as potential direct capping materials because of their superior ability to adhere to both demineralized enamel and dentin tissues. Hybridization of DBAs with demineralized intertubular collagen, as well as the diffusion of adhesives into the dentin tubules, may seal the vital dentin against bacterial leakage and reduce secondary pulpal inflammation.

According to Brannstrom et al, success in direct pulp capping depends on prevention of microleakage. Hence, the agents that seal and bond to the tooth structure started receiving more attention especially with the evolution of dentin bonding agents.

Dentin bonding agents are low viscosity resins that form micromechanical bonding to the tooth structure by penetrating the demineralized collagen meshwork and forming hybrid zones. This is to provide microleakage resistant barrier. Therefore, dentin-bonding agents were proposed as pulp capping materials. However, there are some drawbacks of DBA. The etching creates osmotic shrinkage of the odontoblasts. Also, organic solvents like ethanol or acetone can destroy odontoblastic processes. It has also been postulated that the unpolymerized part of resin is toxic to pulpal cells. The longevity of the bond and resistance to microleakage is not established.

Histological Evaluation of Pulp after One Week

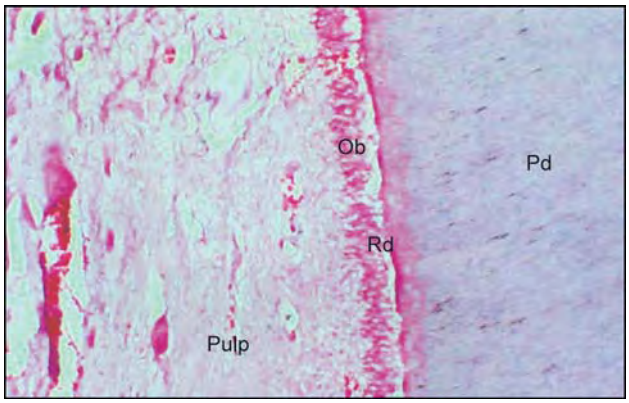


Fig. 8.3E: Dentin bonding agent + composite (10X)

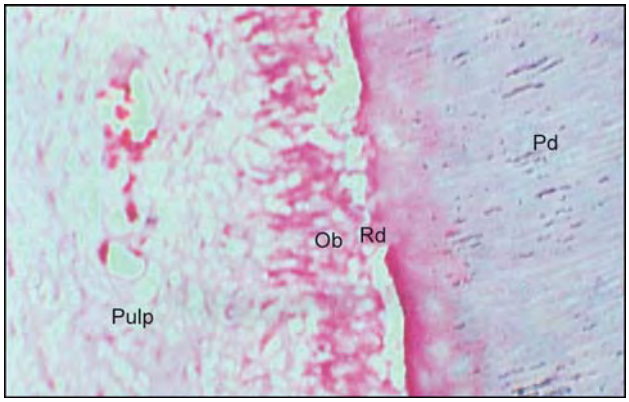


Fig. 8.3F: Dentin bonding agent + composite (25X)

Histological Evaluation of Pulp after Two Weeks

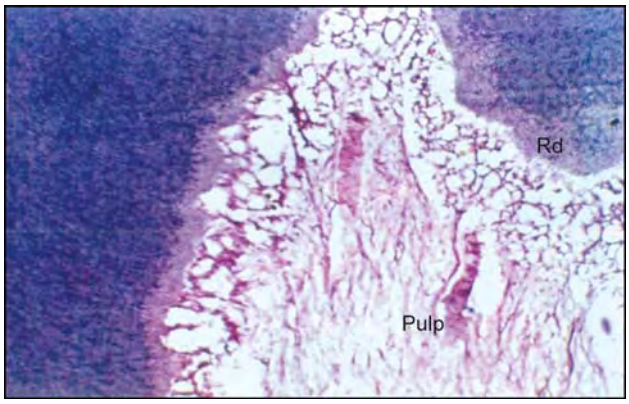


Fig. 8.3G: Dentin bonding agent + composite (10X)

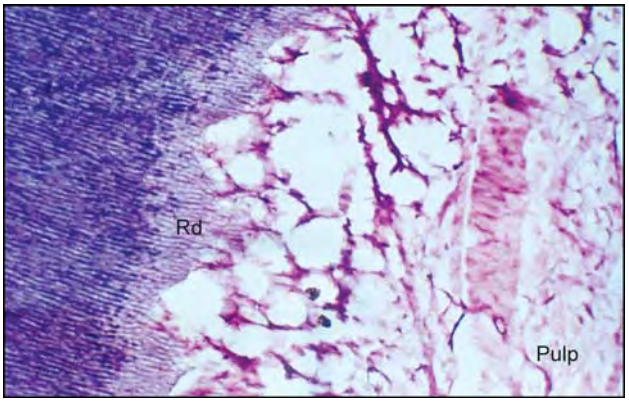


Fig. 8.3H: Dentin bonding agent + composite (25X)

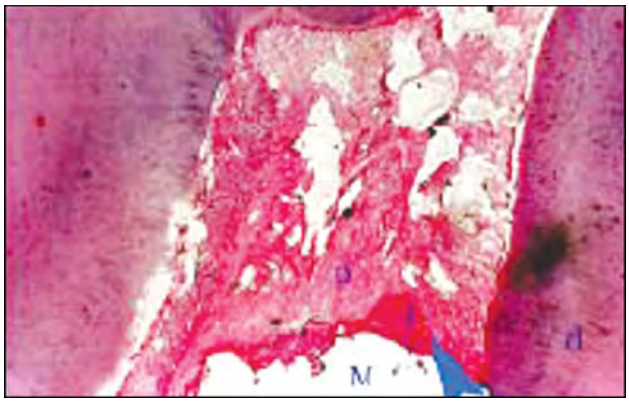


Fig. 8.4: Pulp capping with MTA

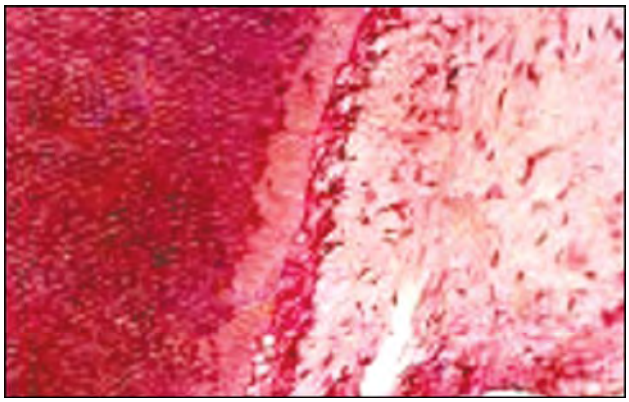


Fig. 8.5: Pulp capping with MTA calcific barrier

MINERAL TRIOXIDE AGGREGATE

Mineral trioxide aggregate (MTA) was developed at Loma Linda University for use as a root-end filling material in surgical endodontic treatment. It has been patented, has received the approval of the Federal Drug Administration (FDA) in the USA and is commercially available as ProRoot MTA. Initially a gray version was produced but more recently a white version has become available.

It consists of fine hydrophilic particle that sets in presence of moisture. Hydration of the powder results in a colloidal gel that solidifies to a hard structure. Recently, this material has proved to be a very efficient pulp capping material.

Composition

- Tricalcium silicate
- Dicalcium silicate
- Tricalcium aluminate
- Tetracalcium aluminoferrite
- Bismuth oxide - 20 percent
- Calcium sulfate dihydrate (gypsum) - 5 percent.

The exact mechanism of formation of a calcific barrier by MTA is unknown. Studies have proposed that the calcium oxide present in MTA reacts with tissue fluids to form calcium hydroxide which finally stimulates the hard tissue barrier.

Inflammatory response is less with MTA as compared with calcium hydroxide pulp capping (Figs 8.4 and 8.5)

Apexogenesis or Vital Pulp Therapy

Definition

Defined as the physiologic root end development and formation—American Association of Endodontists.

The current terminology is vital pulp therapy and is defined (Walton and Torabinejad) as the treatment of a vital pulp in an immature tooth to permit continued dentin formation and apical closure.

Objective: To maintain vitality of the radicular pulp allowing development of the entire root and the apex.

This objective is achieved through three distinct procedures:

1. Indirect pulp capping
2. Direct pulp capping
3. Apical closure pulpotomy.

Apical Closure Pulpotomy

This is the treatment of choice whenever an immature permanent tooth with an open apex and reversible

pulpitis suffers a carious exposure or a large diameter (more than 1mm) traumatic pulpal exposure, of any duration, occurs.

Definition: (Andreasen) It is defined as the removal of damaged and inflamed tissue to the level of a clinically healthy pulp, followed by a calcium hydroxide dressing.

It was described in 1938 by Teuscher and Zander. Kaiser in 1964 and Frank in 1966 popularized the technique. It became famous as "Frank's technique".

Depending on the size of exposure and time elapsed since injury, different levels are described:

1. Partial pulpotomy, also known as shallow, low-level or Cvek's pulpotomy.
2. Cervical pulpotomy, also known as deep, high-level, total or conventional pulpotomy.

Neither exposure size nor time interval between injury and treatment are critical for healing when the pulp is reversibly inflamed.

Materials: The contemporary materials are calcium hydroxide and MTA.

Calcium Hydroxide Pulpotomy

Partial Pulpotomy

Cvek reported a high success rate of 94-96 percent with this procedure, when carefully performed. This is also a permanent procedure if root closure occurs, not requiring subsequent RCT unless there is a need for post and core treatment.

Technique

1. Anesthetize and isolate.
2. A diamond bur, corresponding to the size of the exposure in a high speed contra-angle handpiece, is used with water spray to provide effective cooling.
3. Cutting is performed intermittently for brief periods and without undue pressure.
4. Level of amputation is 2 mm below the exposure site. This provides for removal of inflamed tissue and adequate cavity for dressing and sealing material. The cavity is made box-like with undercuts for retention.
5. Pulpal wound is rinsed with saline till bleeding ceases. Hemorrhage can be controlled with moist cotton pellets applied with light pressure.
6. Wound is covered with calcium hydroxide, which is adapted with light pressure. Surplus is removed with spoon excavator.
7. Cavity is sealed with IRM or GIC.

Advantages of Partial Pulpotomy

a. Minor injury to the pulp and undisturbed physiologic apposition of dentin, especially in the critical cervical area of the tooth.
b. The limited loss of coronal pulp allows for vitality testing.
c. Limited loss of crown precludes need for post and core.

Cervical Pulpotomy

This is indicated when necrotic tissue or obviously impaired circulation is present at the site of exposure in the immature tooth. Here, pulp should be amputated to a level at which fresh bleeding tissue is found, i.e. at cervical level. Bleeding should be controllable.

Due to problems with adequate cooling of the diamond bur at high speed at that level, a round carbide bur at low speed should be used. For, molars, a spoon excavator can be used to amputate pulp till the floor level.

When using calcium hydroxide powder, Webber recommends the addition of barium sulfate, in the ratio of 4 parts calcium hydroxide and 1 part barium sulfate. This increased radiopacity will enable radiographic confirmation of apposition of calcium hydroxide onto the orifices (pulp stumps), which is essential for the therapy to be effective.

Histology

There are three identifiable zones in 4-9 days:

1. Coagulation necrosis
2. Deep staining basophilic areas with varied osteodentin.
3. Relatively normal pulp tissue, slightly hyperemic, underlies an osteoblastic layer.

Pulpotomy with MTA (Torabinejad)

The procedure is similar to that described for calcium hydroxide. Here, MTA is mixed with saline in a ratio of 3:1 and is placed against the pulp stump. It is lightly patted against the pulp and a moist cotton pellet is placed against it to enable setting, as it sets in the

presence of moisture. The cavity is sealed with IRM or GIC.

Other materials: Newer materials such as Bone Growth Factors and Bone Morphogenetic Proteins are under research and have shown to be successful.

Recall for Apexogenesis

The total time treatment is 1-2 years, based primarily on extent of root development at the time of procedure. Recall is at 3 month intervals to determine pulpal vitality and extent of apical maturation. In contrast to apexification, the paste does not need changing.

Apexification

Traditionally the treatment for immature permanent teeth with necrotic pulps was periapical surgery with retrograde amalgam fill. However, as it had many shortcomings, various non-surgical approaches were attempted (discussed by Morse):

- Blunt end or rolled cone (customized cone)
- Short fill technique (by Moodnick)
- Instrumentation only
- No treatment
- Induction of periapical bleeding with instruments (by Nygaard-Ostby)
- Apexification and apical barrier technique.

Of these, apexification was found to be the one with consistently good results. Obturation without root end closure was generally unsuccessful because even though the cone would fit mesiodistally, the buccolingual aspect would not be sealed as this is the last to become convergent as root develops. This buccolingual aspect is not visible radiographically.

Definition

Defined as the method of inducing apical closure by the formation of osteocementum or a similar hard tissue or the continued apical development of the root of an incompletely formed tooth in which the pulp is no longer vital—American Association of Endodontics.

This procedure can be employed in both children and adults.

A more recent term is "Root-End Closure", introduced by Torabinejad in 2002. It is defined as the process of creating an environment within the root canal and periapical tissues after pulp death that allows a calcific barrier to form across the open apex. This barrier has been characterized as dentin, cementum, bone, osteodentin and osteocementum.

The usual result of root end closure is blunting of the apex and very little, if any, increase in root length. There is no development of root and the walls are generally thin and fragile. This procedure, however, results in an apical stop, which allows for adequate obturation of the canal.

Indication

Restorable immature tooth with pulp necrosis.

Contraindications

1. All vertical and unfavorable horizontal root fractures.
2. Replacement resorption
3. Very short roots
4. Periodontal breakdown
5. Vital pulps.

Materials and Method

Traditionally, calcium hydroxide was the material of choice, supported by the investigations of many researchers. However, other materials, e.g. tricalcium phosphate, collagen calcium phosphate, osteogenic protein- 1, bone growth factors and mineral trioxide aggregate have been reported to promote apexification similar to calcium hydroxide. The most important factors, though, are thorough debridement of the canal and sealing of the tooth to prevent microleakage.

Average treatment time: 12-18 months

Range: 6-24 months

$Ca(OH)_2$ paste should be replaced as often as necessary. The paste would need to be changed at third recall (6 weeks) if:

a. Paste is found to be wet in apical half due to exudates.
b. Radiographic evidence of dilution of paste, i.e. more radiolucent.
c. Paste is overextended at second appointment.
d. Patient develops sinus tract or symptoms in early months of treatment.

New Materials Used for Apexification

Osteogenic Protein - 1

This is a bone morphogenetic protein. It is believed to attract and recruit mononuclear phagocytes to sites of bone formation. It also stimulates the proliferation of mesenchymal cells that subsequently differentiate into osteogenic cells. This material is used with a collagen carrier which allows its release over a long period.

Bone Growth Factors

Studies have shown that bone growth factors such as TGF-β, IGF-I, PDGF delivered in carboxymethyl cellulose carriers can induce apical closure.

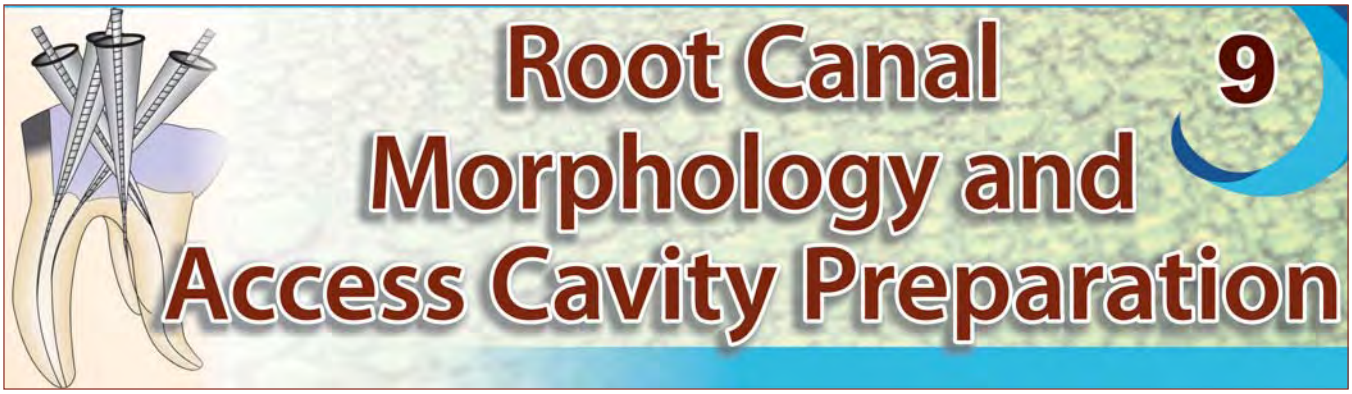
Apexogenesis vs Apexification

Apexogenesis results in complete root development and not only apical closure. On the other hand, apexification may result in result in apical closure, but the root still remains short with thin walls in most cases. Thus, it is important to maintain pulpal vitality by early initiation of treatment so as to achieve complete root development.

SUGGESTED READING

1. Bergenholtz G, Cox CF, Loesche WJ, Syed SA. Bacterial leakage around dental restorations: its effect on the dental pulp. J Oral Pathol 1982;11:439 -50.
2. Cox CF, Su¨ bay RK, Ostro E, Suzuki S, Suzuki SH. Tunnel defects in dentin bridges: their formation following direct pulp capping. Oper Dent 1996;21:4-11.
3. Cox CF, Keall CL, Keall HJ, Ostro E, Bergenholtz G. Biocompability of surface-sealedmaterials against exposed pulps. J Prosthet Dent 1987;57:1-8.
4. Costa CAS, Hebling J, Hanks CT. Current status of pulp capping with dentin adhesive systems: a review. Dent Mater 2000;16:188-97.
5. C¸ ehreli ZC, Onur MA, Tas¸man F, Gu¨mru¨ kc¸u¨ og–lu A, Artuner H. Effects of current and potential dental etchants on nerve compound action potentials. J Endod 2002;28:149-51.
6. Costa CAS, Vaerten MA, Edwards CA, Hanks CT. Cytotoxic effects of current dental adhesives systems on immortalized odontoblast cell line MDPC-23. Dent Mater 1999;15:434-41.
7. Costa CAS, Teixeira HM, Nascimento ABL, Hebling J. Biocompatibility of an adhesive system and 2-hydroxyethylmethacrylate. J Dent Child 1999;66:337-42.
8. Costa CAS, Teixeira HM, Nascimento ABL, Hebling J. Biocompatibility of two current adhesive resins. J Endod 2000;26:512-16.
9. Costa CAS, Nascimento ABL, Teixeira HM, Fontana UF. Response of human pulps capped with a self-etching adhesive system. Dent Mater 2001;17:230-34.
10. Costa CAS, Hebling J, Hanks CT. Current status of pulp capping with dentin adhesives: a review. Dent Mater 2000;16:188-97.
11. Demarco FF, Tarquino SBC, Jaeger MMM, Araujo VC, Matson E. Pulp response and cytotoxicity evaluation of 2 dentin bonding agents. Quintessence Int 2001;32:211-20.
12. Gwinnet AJ, Tay FR. Early and intermediate time response of the dental pulp to an acid etch technique in vivo. Am J Dent 1998;11:35-44. (Special Issue)
13. Goldberg M, Six N, Decup F, Lasfargues JJ, Salih E, Tompkins K, Veis A. Bioactive molecules and the future of pulp therapy. Am J Dent 2003;16:66-76.
14. Hanks CT, Wataha JC, Parsell RR, Strawn SE. Delineation of cytotoxic concentrations of two dentin bonding agents in vitro. J Endod 1992;18:589-96.
15. Hebling J, Aparecida EM, de Souza Costa CA. Biocompatibility of an adhesive system applied to exposed human dental pulp. J Endod 1999;25:676-82.
16. Heys DR, Fitzgerald M, Heys RJ, Chiego DJ. Healing of primate dental pulps capped with Teflon. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1990;69:227-37.
17. Hafez AA, Cox CF, Tarim B, Otsuki M, Akimoto N. An in vivo evaluation of hemorrhage control using sodium hypochlorite and direct capping with a one- or two-component adhesive systems in exposed non-human primate pulps. Quintessence Int 2002;33:261-72.
18. Kitamura C, Ogawa Y, Morotomi T, Terashita M. Differential induction of apoptosis by capping agents during pulp wound healing. J Endod 2003;29:41-43.
19. Kitasako Y, Inokoshi S, Tagami J. Effects of direct resin capping techniques on short term mechanically exposed pulps. J Dent 1999;27:257-63.
20. Murray PE, Stanley HR, Matthews JB, Sloan AJ, Smith AJ. Age-related odontometric changes of human teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;93:474-82.
21. Pereira JC, Segala AD, Costa CAS. Human pulpal response to direct pulp capping with an adhesive system. Am J Dent 2000;13:139-47.
22. Pitt Ford TR. Pulpal response to a calcium hydroxide material for capping exposures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1985;59:194-97.
23. Pameijer CH, Stanley HR. The disastrous effects of the "Total Etch" technique in vital pulp capping in primates. Am J Dent 1998;11:45-54 (Special Issue).
24. Ratanasathien S, Wataha JC, Hanks CT, Dennison JB. Cytotoxic interactive effects of dentin bonding components on mouse fibroblasts. J Dent Res 1995;74:1602-06.

25. Schro¨der U. Effects of calcium hydroxide-containing pulp capping agents on pulp cell migration proliferation and differentiation. J Dent Res 1985;64:541-48.
26. Schmalz G. The biocompatibility of non-amalgam dental filling materials. Euro J Oral Sci 1998;106:687-95.
27. Schuurs AHB, Gruythuysen RJM, Wesselink PR. Pulp capping with adhesive resinbased composite vs. calcium hydroxide: a review. Endod Dent Traumatol 2000;16: 240-50.
28. Su¨bay RK, Cox CF, Kaya H, Tary´m B, Su¨bay AA, Nayy´r M. Human pulp reaction to dentine bonded amalgam restorations: a histologic study. J Dent 2000;28:327-32.
29. Stanley HR. Pulp capping. Conserving the dental pulp. Can it be done? Is it worth it? Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1989;68:628-39.
30. Sloan AJ, Smith AJ. Stimulation of the dentine-pulp complex of rat incisor teeth by transforming growth factor-_ isoforms 1-3 in vitro. Arch Oral Biol 1999;44:149-56.
31. Tziafas D, Smith AJ, Lesot H. Designing new treatment strategies in vital pulp therapy.J Dent 2000;28:77-92.
32. Tarim B, Ersev H, Dis¸ci R, Hafez AA, Kahn RL, Cox CF. Temperature rise during composite resin polymerization with various light-curing units through dentin [abstract No:3436]. J Dent Res 2002;81. (Spec Issue A)
33. Yoshiba K, Yoshiba N, Nakamura H, Iwaku M, Ozawa H. Immunolocalization of fibronectin during reparative dentinogenesis in human teeth after pulp capping with calcium hydroxide. J Dent Res 1996; 75:1590-97.



Access is the first and arguably the most important phase of root canal treatment. A well designed access preparation is essential for good endodontic success. Without adequate access, it is difficult to manipulate instruments and materials in highly complex and variable root canal system. The basic principles of obtaining straight line access to the apical foramen. Complete de roofing of the chamber wall along with conservation of tooth structure holds good till today.

To achieve optimal access preparation, three factors of internal anatomy must be considered:

1. Pulp chamber size
2. Pulp chamber shape
3. Number of root canals, their position and their curvature.

Pulp chamber size: Variations in the outline of pulp chamber invariably affect the outline of the access cavity. In young patients, these preparations must be more extensive than in older patients, as the pulp is receded and is three dimensionally smaller.

Pulp chamber shape: The outline form should accurately reflect the shape of the pulp chamber. Example, the floor of the pulp chamber in a molar tooth is usually triangular in shape, due to the shape and position of the canal orifices. This triangular shape is extended up the walls of the cavity and outer occlusal surface; hence, the final occlusal cavity outline form is generally triangular. While the coronal pulp of a maxillary premolar is flat mesiodistally but is elongated buccolingually. The outline form is, therefore, an elongated oval that extends buccolingually rather than mesiodistally, as opposed to Black's operative cavity preparation.

Number, Position, and Curvature of Root Canals. The third factor regulating outline form is the number, position, and curvature or direction of the root canals. To prepare each canal efficiently without interference, the cavity walls often have to be extended to allow an unstrained instrument approach to the apical foramen. This change is for convenience in preparation; hence, convenience form partly regulates the ultimate outline form.

ROOT CANAL ANATOMY

Krasner and Rankow in a study of 500 pulp chambers determined that the cemento-enamel junction was the most important anatomic landmark for determining the location of pulp chambers and root canal orifices. They demonstrated that specific and consistent pulp chamber floor and wall anatomy exists and proposed laws for assisting clinicians to identify canal morphology. The relationships expressed in these laws are particularly helpful in locating calcified canal orifices.

These laws are:

1. *Law of symmetry 1:* Except for maxillary molars, the orifices of the canals are equidistant from a line drawn in a mesiodistal direction through the pulp chamber floor.
2. *Law of symmetry 2:* Except for maxillary molars, the orifices of the canals lie on a line perpendicular to a line drawn in a mesiodistal direction across the center of the floor of the pulp chamber.
3. *Law of color change:* The color of the pulp chamber floor is always darker than the walls.
4. *Law of orifices location 1:* The orifices of the root canals are always located at the junction of the walls and the floor.

5. *Law of orifices location 2:* The orifices of the root canals are located at the angles in the floor-wall junction.
6. *Law of orifices location 3:* The orifices of the root canals are located at the terminus of the root developmental fusion lines.

The above laws were found to occur in 95 percent of the teeth examined. Five percent of mandibular second and third molars did not conform to these laws because of the presence of C-shaped canal anatomy.

The pulp cavity generally decreases in size as age advances. Dentine formation is not uniform throughout life and is more rapid on the roof and floor than on the walls of pulp chambers of posterior teeth. Such calcifications result in a flattened pulp chamber. There is a variation in radiographic and clinical finding with respect to root canal size and shape. In some of the cases radiograph shows narrow, calcified canals but when the pulp chamber is opened it shows normal anatomic parameters. The direction that a file takes upon introduction into an orifice is also important. If the initial file placed into the distal canal of a mandibular molar, for example, points to the buccal or lingual, one should suspect a second canal. If two canals are present in the distal root of mandibular molar, direction of the file guides the clinician to locate the second canal, i.e. the file will not be centrally located as in case of single canal.

Classification of Canal Morphology (Figs 9.1A to C)

The complexity of root canal system has been attempted to be classified by many researchers. Weine gave a simple but a basic classification of root canal morphology. Later, Vertucci found more complex pulp space system in his cleared sections and classified pulp space into eight different configurations.

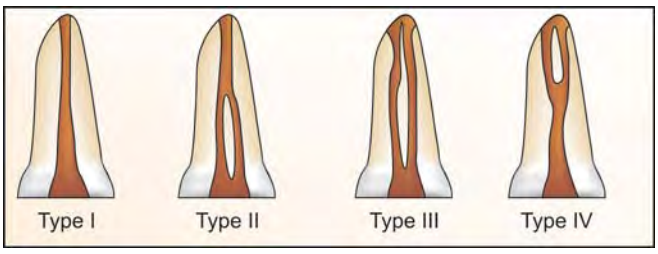


Fig. 9.1A: Weine's classification of root canal morphology

Weine's Classification of Root Canal Morphology (Fig. 9.1A)

Type I: single canal extends from pulp chamber to apex.

Type II: Two separate canals leaving the pulp chamber but merging short of apex to form only one canal.

Type III: Two separate canals leaving the chamber and exiting the root in separate apical foramina.

Type IV: One canal leaving the pulp chamber and divides short of apex into two separate and distinct canals with separate apical foramina.

Vertucci's Classification (Fig. 9.1B)

Type I: A single canal extends from pulp chamber to apex (1).

Type II: Two separate canals leave the pulp chamber and join short of apex to form one canal (2-1).

Type III: One canal leaves the pulp chamber and divides into two in the root; the two then merge to exit as single canal (1-2-1).

Type IV: Two separate, distinct canals extend from pulp chamber to apex (2).

Type V: One canal leaves the pulp chamber and divides short of apex into two separate, distinct canals with separate apical foramina (1-2).

Type VI: Two separate canals leave the pulp chamber; merge in body of the root, and redivide short of apex and exits as two distinct canals (2-1-2).

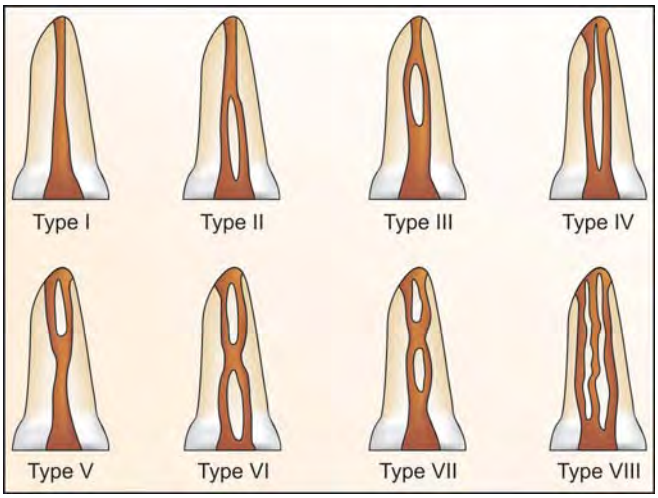


Fig. 9.1B: Diagrammatic representation of Vertucci's canal configurations

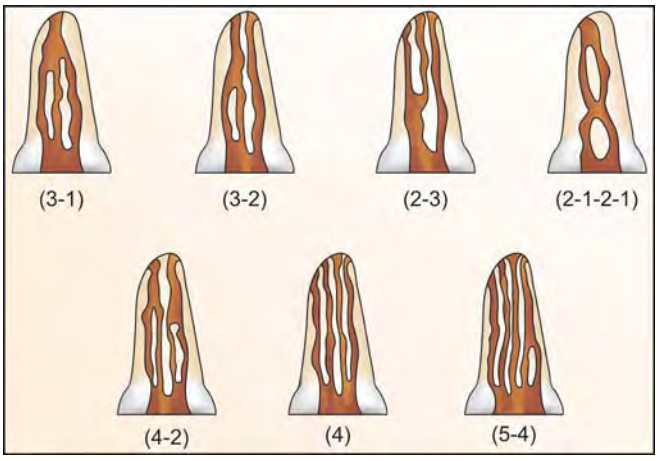


Fig. 9.1C: Gulabivala's modification

Type VII: One canal leaves the pulp chamber; divides and then rejoins in the body of the root, and finally divides into two distinct canals short of apex (1-2-1-2).

Type VIII: Three separate distinct canals extend from pulp chamber to apex (3).

Gulabivala also added certain modifications to Vertucci's classification (Fig. 9.1C).

ACCESS CAVITY PREPARATION

Access cavity preparation is very important for proper biomechanical preparation and obturation.There are slight variations in access cavity preparation for individual teeth, but there are certain common steps for similar types of teeth.

This can be divided as:

1. Anterior access cavity preparation
2. Posterior access cavity preparation.

Anterior Access Cavity Preparation

Caries should be excavated completely before the pulp chamber is entered or else there is a risk of contamination with bacteria during endodontic treatment.

Removal of Permanent Restorations and Crowns

It is ideal to remove permanent restoration before access cavity preparation in order to gain a straight line access and to prevent coronal leakage.

In some cases, if the restoration extends subgingivally, it is better to remove the occlusal restoration and retain the proximal restoration for applying the rubber dam.

Some clinicians may prefer to perform endodontic treatment retaining the crowns and restorations, if they are intact and do not necessitate replacement.

Initial External Outline Form

The approach should be lingual just above the cingulam and perpendicular to the long axis of the tooth with no. 2 and no. 4 round burs.

The outline form follows the outline form of the crown. The removal of enamel can be done with an airotor handpiece directed perpendicular to the lingual surface.

Penetration of the Pulp Chamber

Enamel and dentin are removed till a thin layer of dentin remains on the roof of pulp chamber. Then to enter pulp chamber a low speed handpiece and round bur should be used. A "drop" will be felt in effect due to the lesser resistance of the pulp.

Sometimes it may not be possible to feel the drop. Then one should carefully examine the radiograph in order to find out the cause.

Complete Roof Removal

Once the pulp chamber has been penetrated, the remaining roof is removed with a slow speed handpiece, from the inner wall to the outer portion of the roof of the pulp chamber. This should be done to preserve the road map and because each tooth has some variation in outline form.

In a vital tooth, hemorrhage may impair the clinician's ability to see the internal anatomy. In such cases, the coronal pulp should be amputated with the spoon excavator upto the orifice of the pulp chamber. If the hemorrhage cannot be controlled, then sodium hypochlorite irrigation should be used so that the pulp chamber can be cleaned and one can visualize the orifices of the root canals.

An endodontic explorer or smooth broach can be used to locate the orifices of the canals.

Removal of Lingual Shoulder and Orifice and Coronal Flaring

Once the canal openings are identified, the lingual shoulder is removed. The removal of lingual shoulder

aids in straight line access of the files with the canals. Lingual shoulder can be removed with a tapered safety diamond or carbide bur or Gates Glidden burs. The bur can be placed 2 mm below the lingual shoulder and inclined towards the lingual surface. If necessary, clinicians can use increased bur size to round up the lingual shoulder.

During this process, the orifice should also be flared up so that it can merge with the access cavity preparation. This can be done with small Gates Glidden drills increased sequence-wise to larger numbers.

To prevent perforation of the thin walls, the bur should be placed casually in the canal and rotated gently.

Another approach to flare up the canal orifice is by using Ni-Ti rotary instruments.

Straight Line Access Determination

After the removal of lingual shoulder and orifice flaring, the clinician should determine straight line access to the canals by using endodontic explorers and smooth broaches. After determining straight line access, various files can be used to remove infected dentine.

Finally, success of access cavity preparation is determined by two factors:

1. Complete de-roofing of pulp chamber.
2. Straight line access.

Visual Inspection of Access Cavity

Finally, the clinician should examine the access opening by using various magnification methods such as loupes, magnifying glasses or the operating microscope, whichever is ideally suitable.

Refinement of Restorative Margins

The final step in access cavity preparation is to smoothen the cavosurface margins and restorative material. It is very important to prevent coronal leakage of the temporary or permanent restorations.

Posterior Access Cavity Preparation

The preparation of access cavity for posterior teeth is similar to that of anterior teeth except for certain variations. These variations are due to:

i. Morphology of tooth structure
ii. Numerous canals present in posterior teeth

Removal of Caries and Permanent Restorations

The same rules should be followed for posterior teeth as for anterior.

Initial External Outline Form

This outline form differs slightly for each individual posterior tooth, for example in upper premolars the access opening is in the buccolingual center of the tooth. In lower premolars, due to the prominence of the buccal cusp and the rudimentary lingual cusp, the access opening should be towards the lingual slope of the buccal cusp. Also, in the upper 1st premolars, usually 2 canals are present, so, the access opening should be extended upto buccal and palatal cusp tips.

For lower molars, the access opening is triangular in shape with the tip of the cone towards the central pit and the base towards the mesial surface. It is better to locate the larger canal first, i.e. distal canal and then proceed to locate the other canals. Sometimes, it may be rhomboid in shape due to presence of more than 3 canals. For upper molars too, the access opening is triangular in shape with the cone tip towards palatal surface and the base towards the buccal surface. There may be slight variations in design of the pulp chamber depending upon the number of canals. Here also the same rule applies, i.e. location of the larger canal (palatal) and then the rest. MB-2 is found in 60 percent of the cases in upper molars. It may be difficult to locate sometimes. In such cases magnifying methods may be used.

Penetration of the pulp chamber and roof, complete roof removal, and identification of all canal orifices are the same as in anterior teeth.

Removal of Cervical Dentin Bulges and Orifice and Coronal Flaring

In posterior teeth, dentin bulges and natural coronal canal constriction may prevent the location of the canal orifices. So the cervical bulge of dentin, which is seen as an overhang on the orifice, should be removed. The rest of the principles match those in the anterior teeth.

ROOT CANAL ACCESS PREPARATION IN UNUSUAL CIRCUMSTANCES

1. *Teeth with minimal or no clinical crown:* This includes the teeth with extensive carious involvement, restorative build-up and traumatic injuries. Loss

of coronal anatomy creates problem for proper guidance of access preparations. Before beginning the access preparation, the radiograph should be examined carefully. The clinical crown anatomy should be carefully assessed as there may be excessive damage towards the walls of the canals. In these circumstances placement of rubber dam may be difficult.

It is better to prepare the access cavity and locate the canals before applying the rubber dam. Alternatively, one can build the clinical crown with a suitable material that may aid in rubber dam application.

2. *Heavily restored teeth:* Sometimes it may be difficult or impractical to remove the existing restorations or crowns which may have changed the occlusal table. In these circumstances, it is difficult to assess the pulp chamber by a radiograph. These problems become more complicated in cases of narrow pulp chamber and presence of pulp stones. The restorations prevent visibility of the canal after opening the pulp chamber.

   Careful assessment of the canals is done by taking radiographs in different angulations. The patient is explained about the difficulties in such situations and the prognosis.
3. *Teeth with calcified canals and pulp stones:* Radiographic examination is very important to see whether pulp stones can be removed or bypassed by using various types of endodontic instruments. It is not easy to remove the pulp stones which are attached to the floor of the pulp chamber. In these cases, careful access preparation using magnification methods is mandatory.
4. *Crowded teeth:* Conventional access cavity preparation may be difficult in these cases. Access opening may have to be altered. Sometimes buccal approach may be taken in anterior and smaller canals may have to be located first in posteriors.
5. *Rotated teeth:* In this case, the problem may be due to the crown and root relationship. Perforation commonly occurs in these cases due to faulty angulations of the bur.

   Mistake in identifying or locating canals results due to wrong direction. It may also lead to failure to locate extra canals, removal of excessive coronal tooth structure and failure to remove the complete roof and adequate debridement of the pulp chamber.

With the help of proper radiographs, the errors may be minimized or corrected.

Variations in Root Canal Morphology (Figs 9.2 and 9.3)

Root canal system is a complex anatomical structure present between canal orifices and the apex. The canals may present different ramifications such as branching, division and reunion. Apart from these, root canal system may also present ramifications such as multiple foramina, lateral and accessory canals, fins, deltas, intercanal connections, loops and C-shaped canals. These ramifications may present a challenge to the clinician, in diagnosis, cleaning and shaping and obturation.

MB-2 CANAL IN MAXILLARY MOLAR (FIGS 9.4A AND B)

The mesiobuccal root of the maxillary first molar has generated more research and clinical investigation than any root in the mouth. It generally has two canals but a third canal has been reported. When there are two, they are called mesiobuccal-1 (MB-1) and second mesiobuccal (MB-2). MB-2 is consistently located mesial to or directly on a line between the MB-1 and

Fig. 9.2: Cleared teeth showing anatomic variations

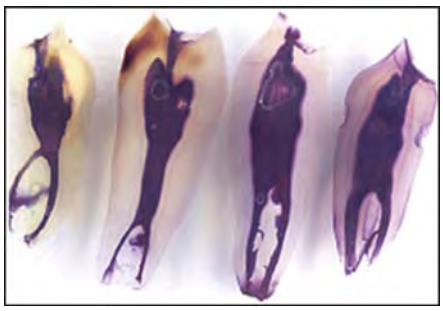
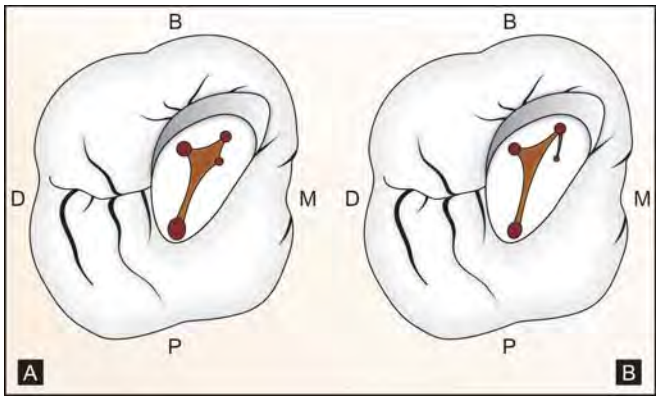


Fig. 9.3: Cleared teeth showing anatomic variations



Figs 9.4A and B: Diagrammatic representation of position of MB-2 canal orifice in maxillary molars

the palatal orifices, within 3.5 mm palatally and 2 mm mesially from the MB-1 orifices. Not all MB- 2 orifices lead to a true canal. An "apparent" MB-2 canal could not be traced far beyond the orifices in 16 percent of the teeth.

Negotiation of the MB-2 canal is often difficult due to a shelf of dentine that covers its orifices, the mesiobuccal inclination of its orifices on the pulpal floor and its pathway that often takes one or two abrupt curves in the coronal part of the root. Most of these obstructions can be eliminated by "troughing or countersinking" with ultrasonic tips mesially and apically along the mesiobuccal-palatal groove. This procedure causes the canal to shift mesially necessitating moving the access wall further mesially. Troughing may have to extend 0.5-3.0 mm deep. Care must be taken to avoid furcal wall perforation of this root as a concavity exists on its distal surface. Apical to the troughing level the canal may be straight may curve sharply to the distobuccal, buccal or palatal.

ANATOMIC VARIATIONS IN MANDIBULAR MOLARS

Radix Entomolaris

Mandibular molars usually have two roots. However, occasionally three roots are present with two or three canals in the mesial and one, two, or three canals in the distal root. De Moor et al reported that mandibular first molars occasionally have an additional distolingual root (radix entomolaris, RE). The occurrence of these three-rooted mandibular first molars is less than 3- 5 percent.

Middle Mesial Canal

A middle mesial canal is sometimes present in the developmental groove between MB and ML canals. The incidence of occurrence of an MM canal ranges from 1 to 15 percent. It must always be looked for during access preparation. A bur is used to remove any protuberance from the mesial axial wall which would prevent direct access to the developmental groove between MB and ML orifices. With magnification, this developmental groove should be carefully explored with the sharp tip of an endodontic explorer. If a depression or orifices is located, the groove can be troughed with ultrasonic tips at the expense of its mesial aspect until a small file can negotiate this intermediate canal. The canals in the distal root are the distal (D) if there is one canal and the distobuccal (DB), distolingual (DL) and middle distal (MD) canal if there are more than one canal.

C-shaped Canals (Fig. 9.5)

The C-shaped canal configuration was first reported by Cooke and Cox. While most C-shaped canals occur in the mandibular second molar, they have also been reported in the mandibular first molar, the maxillary first and second molars and the mandibular first premolar. C-shaped mandibular molars are so named because of the cross-sectional morphology of its root

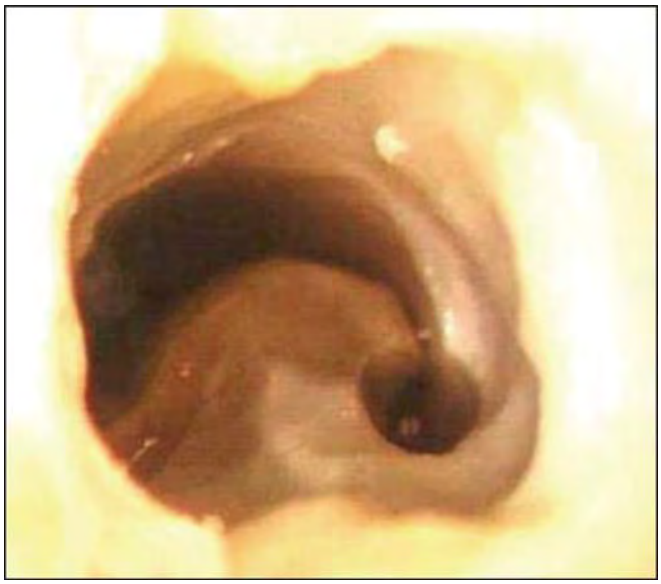


Fig. 9.5: C-shaped canal

and canal. Instead of having several discrete orifices, the pulp chamber of the C-shaped molar is a single ribbon-shaped orifices with a 180-degree arc (or more), starting at the mesiolingual line angle and sweeping around either the buccal or lingual to end at the distal aspect of the pulp chamber. Below the orifices level, the root structure of a C-shaped molar can harbor a wide range of anatomic variations.

These can be classified into two basic groups:

- Those with a single, ribbon like, C-shaped canal from orifices to apex
- Those with three or more distinct canals below the usual C-shape orifices.

More common is the second type of C-shaped canal, with its discrete canals having unusual forms. There is significant ethnic variation in the incidence of C-shaped molars. This anatomy is much more common in Asians, than in Caucasians. Investigations in Japan and China showed a 31.5 percent incidence of C-shaped canals.

The C-shaped canal anatomy creates considerable technical challenges. Access opening for C-shaped canal is difficult as canal orifices are located at a lower level and they are connected in C shape. Extirpation of pulp may be difficult leading to more bleeding which can be mistaken for perforation. Removal of pulp tissue at coronal isthmus is difficult. To overcome these difficulties, the dental operating microscope, sonic and ultrasonic instrumentation and thermoplastic obturation techniques should be used.

RECENT DEVELOPMENTS IN MATERIALS USED FOR ACCESS PREPARATIONS

Endo Access Bur (Fig. 9.6A)

Is a friction grip, stainless steel bur with special diamond coated round tip that matches round burs of size No. 2, No. 4 and No. 6 with a diamond shaft for smoothening and shaping the access walls. These burs are useful for initial and final access preparations. These burs combine both penetration and smoothening capabilities.

Fig. 9.6A: Endo access bur

Fig. 9.6B: Endo Z bur

Endo Z Bur (Fig. 9.6B)

A safe ended diamond or tungsten carbide bur, with a non-cutting tip. It is used to taper the access cavity preparations. The non-cutting tip prevents gouging on the floor of pulp chambers and cavity walls.

Transmetal Bur (Fig. 9.6C)

It is a friction grip, carbide fissure bur designed to cut a metal crown without shattering or breaking. It has extra fine crosscuts.

Great Whites (Fig. 9.6D)

Great Whites are friction grip, crosscut fissure burs used for access preparation and removal of restoration.These effectively cut through semiprecious and non-precious metals and ceramics.

LN Bur, Muller Bur (Fig. 9.6E)

It is a right angled, tungsten steel half round bur mounted on a long neck. The 28 mm length allows deep drilling alongside posts or broken instruments for easier removal and for locating small canal in the roots.

Fig. 9.6C: Transmetal bur

Fig. 9.6D: Great white bur

Fig. 9.6E: LN bur

Fig. 9.6F: Multi-purpose bur

The 32 mm Muller bur is a right angle but similar in design and function to the LN bur. Its round bur, mounted on a long neck is available in six diameter sizes.

Multi-purpose Bur (Fig. 9.6F)

The Maillefer multi-purpose bur is a versatile instrument made from tungsten carbide. The bur is excellent for a variety of procedures including:

- Initial endodontic access
- Sectioning of impacted molars
- Cutting of teeth at root level
- Root separation and amputation of broken roots

RECENT ADVANCE IN THE MANAGEMENT OF BADLY BROKEN DOWN TOOTH

Canal Projection

Canal projection is a technique that rebuilds the pre-endodontic coronal and radicular structure while preserving the individualized access to the canals. Although many syringable and packable materials may be used to project the canals, bondable injectable autopolymerizing composites have proven to be the most versatile and reliable materials for this technique (Figs 9.7 to 9.11).

Advantages

1. *Isolation:* Helps in building up of tooth structure facilitating the application of rubber dam for isolation.
2. *Seal the chamber floor:* Seals the accessory canals, if present in the furcation area and strengthens the chamber floor in cases of badly damaged tooth due to caries in the furcation area.

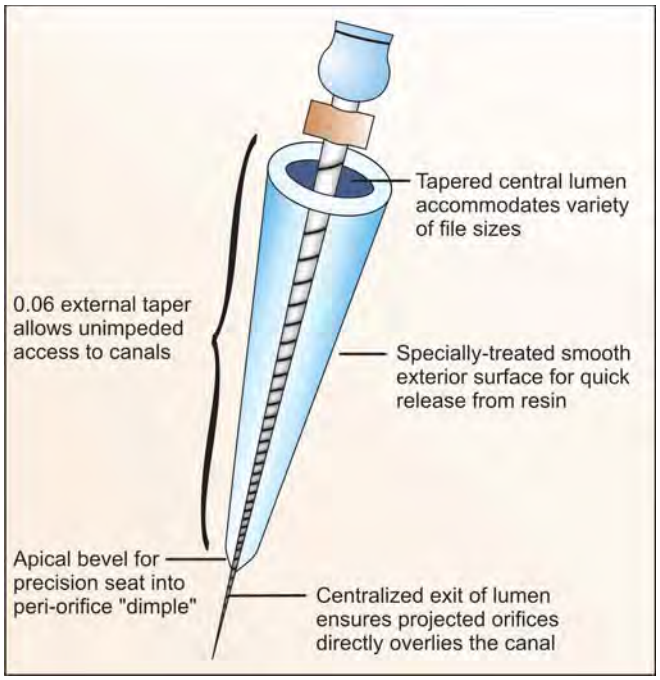


Fig. 9.7: Diagrammatic representation of canal projection system

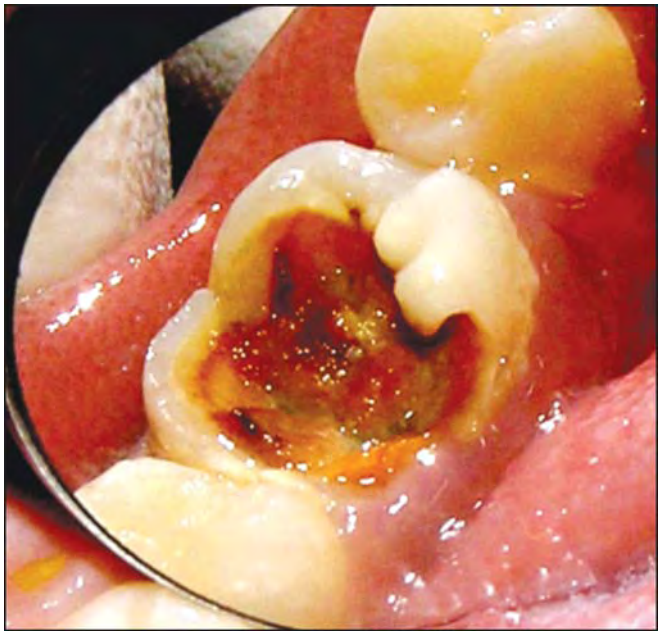
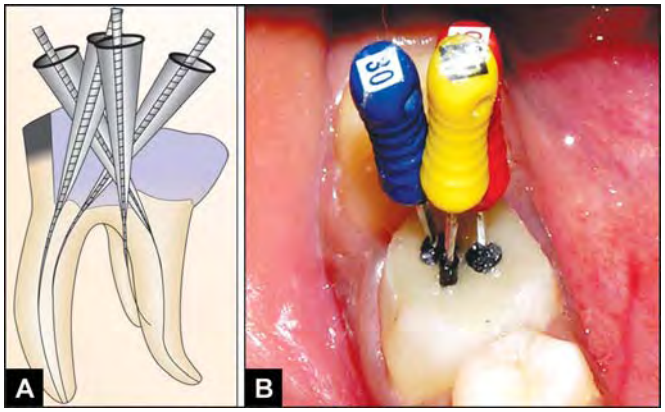


Fig. 9.8: Grossly decayed tooth

3. *Elongation of the canals:* Elongates the hydraulic chamber of each canal from the access cavity floor to occlusal surface offering advantages during hydraulic condensation of obturating materials especially warm vertical condensation techniques.



Figs 9.9A and B: Pre-endodontic build-up using projectors

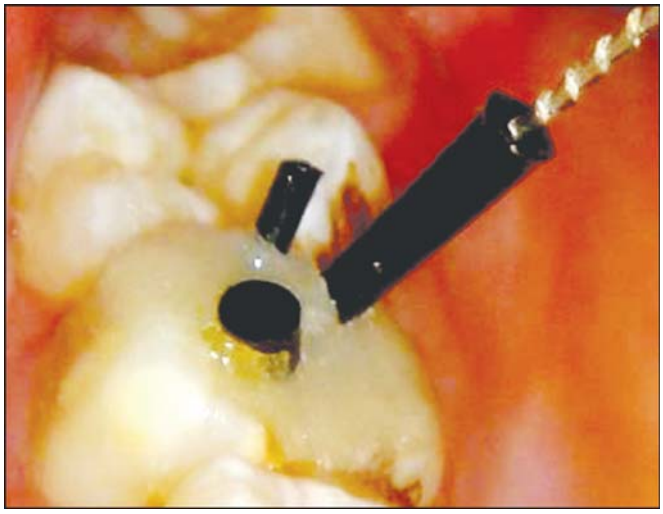
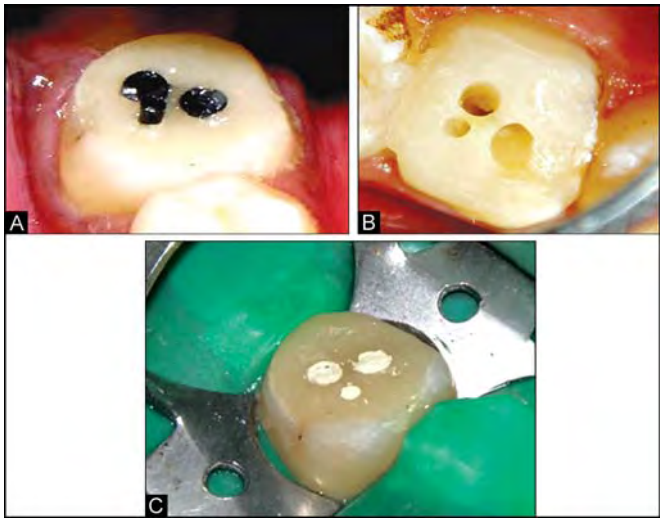


Fig. 9.10: Removal of projectors using H-file



Figs 9.11A to C: Pre-endodontic build-up facilitating placement of rubber dam

4. *Perforations repair and prevention:* Canal projection after the placement of repair materials like MTA offers a means of strengthening the repair area overlying it with a bonded resin or GIC. In case of thin chamber floor, chances of inadvertent perforation are minimized.
5. *Correction of irregularities of chamber floor:* Correction of irregularities of the chamber floor, access cavities, misdirected post preparation an edge.
6. *Reduced potential for crack initiation or propagation:* Placement of pre-endodontic restoration provides cuspal protection to the remaining tooth structure preventing the coronoradicular fracture.
7. *Prevention of ingrowth of tissues:* When defects extends to axial walls at or beyond the gingival level, pre-endodontic build up, as with canal projection eliminates the complexity.
8. *Individualization of the canals:* In multicanal teeth as projectors pass through build up material thus separating the canals and thus individualizing the canals for the use of specific solvents, irrigants, medicaments and lubricants.
9. *Elimination of blind exploration:* As all the canals are projected to occlusal surface, a straight line access is created and projected canals are clearly visible on the occlusal surface, no longer obscured by prominent marginal ridges and other visual obstruction.

CONCLUSION

Access cavity preparation is a very important step for the success of endodontic therapy.

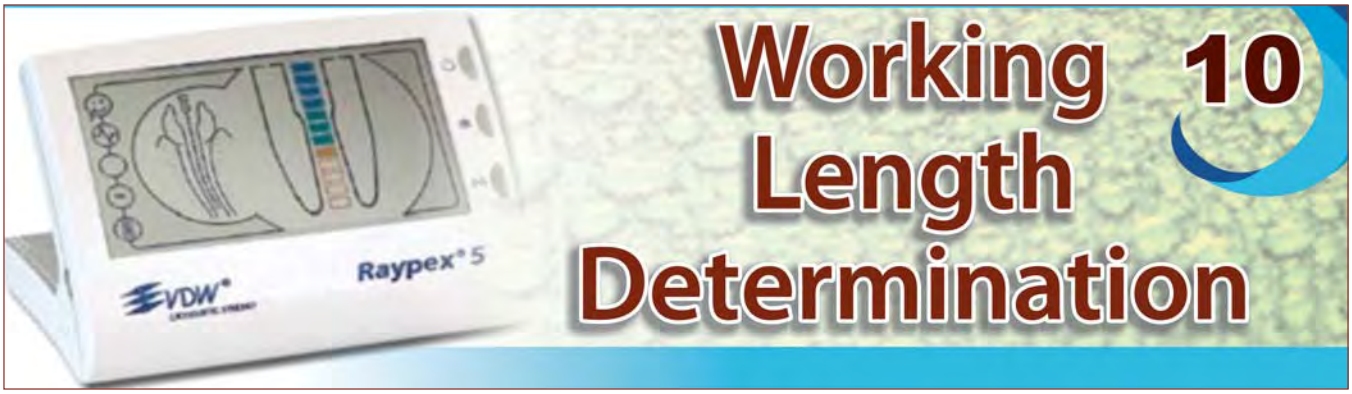
Clinical examinations, radiographs and magnifying methods are very essential for accurate access cavity preparation.

Morphology of tooth structure and the presence of mind also play an important role for proper access cavity preparation. Care should be taken to minimize the errors occurring during access cavity preparation.

SUGGESTED READING

1. Al Shalabi RM, Omer OE, Glennon J, Jennings M, Claffey NM. Root canal anatomy of maxillary first and second permanent molars. International Endodontic Journal 2000;33:405-14.
2. Baugh D, Wallace J. Middle mesial canal of the mandibular first molar: a case report and literature review. J Endod 2004;30:185-86.

3. Bergenholtz G, Spangberg L. Controversies in Endodontics. Crit Rev Oral Biol Med 2004;15:99-114.
4. Cooke HG, Cox FL. C-shaped canal configurations in mandibular molars. J Am Dent Assoc 1979;99:836-39.
5. De Moor RJ, Deroose CA, Calberon FL. The radix entomolaris in mandibular first molars: an endodontic challenge. Int Endod J 2004;37:789-99.
6. Gorduysus MO, Gorduysus M, Friedman S. Operatingmicroscope improves negotiation of second mesiobuccal canals in maxillary molars. J Endod 2001;27:683-86.
7. Gulabivala K, Aung TH, Alavi A, Mg Y-L. Root and canal morphology of Burmese mandibular molars. Int Endod J 2001;34:359-70.
8. Gutierrez JH, Aguayo P. Apical foraminal openings in human teeth - number and location. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:769-77.
9. Krasner P, Rankow HJ. Anatomy of the pulp chamber floor. J Endod 2004;30:5-16.
10. Min KS. Clinical Management of a Mandibular First Molar with Multiple Mesial Canals: A Case Report. J Contemp Dent Pract 2004;(5)3:142-49.
11. Schwarze T, Baethge C, Stecher T, Geurtsen W. Identification of second canals in the mesiobuccal root of maxillary first and second molars using magnifying loupes or an operating microscope. Aust Endod J 2002;28:57-60.
12. Slowey RE. Root canal anatomy: road map to successful endodontics. Dent Clin N Am 1979;23:555-73.
13. Stropko JJ. Canal morphology of maxillary molars, clinical observations of canal configurations. J Endod 1990;25:446-50.
14. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1984;58:589-99.
15. Weine FS. Case report: three canals in the mesial root of a mandibular first molar (?). J Endod 1982;8:517-20.
16. Weine FS, Hayami S, Hata G, Toda T. Canal configuration of the mesiobuccal root of the maxillary first molar of a Japanese sub-population. Int Endod J 1999;32:79-87.
17. Vertucci FJ. Root canal anatomy of the mandibular anterior teeth. J Am Dent Assoc 1974;89:369-71.
18. Yang ZP, Yang SF, Lin YL.C-shaped root canals in mandibular second molars in Chinese population. Dent Traumatol 1988;4:160-63.
19. Weine FS. Endodontic Therapy, 5th edn. St Louis: Mosby-Yearbook Inc., 1996;395-421.



10 Working Length Determination

It is generally accepted that root canal treatment procedures should be limited within the root canal system. The objective of working length determination is to detect the canal terminus and limit the treatment procedure within the root canal system. There are various methods to determine working length such as radiographs, tactile sensation and paper points. Recently, devices have been developed which are able to detect the canal terminus more precisely using the electronic method, which are known as Apex Locators.

SIGNIFICANCE OF WORKING LENGTH

1. The working length determines till where the instruments are placed in canal for the removal debris, metabolities, end products, and other unwanted items from the canal.
2. It will limit the depth to which the canal filling is placed.
3. It will affect the degree of pain and discomfort that the patient will feel following the appointment.
4. If calculated properly, it will play an important role in success of the treatment and if calculated incorrectly may result in treatment failure.

ANATOMICAL CONSIDERATIONS AND TERMINOLOGY (FIG. 10.1)

Simon has stressed the use of terms related to working length determination.

Working Length

Definition: The distance from a coronal reference point to the point at which canal preparation and obturation should terminate. The ideal apical reference point in the canal is "apical stop".

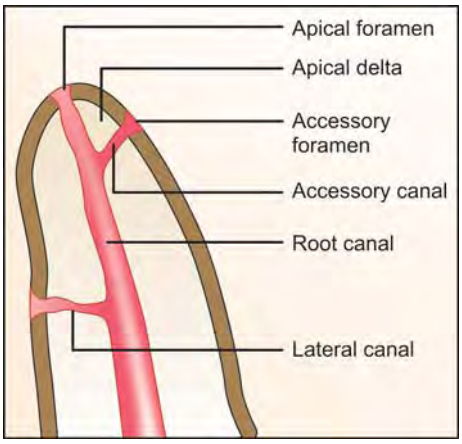


Fig. 10.1: Apical root anatomy

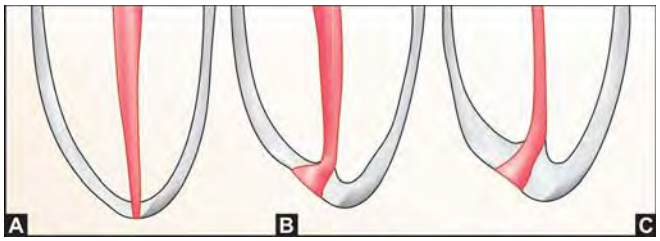
Anatomic apex: Is the tip or the end of the root determined morphologically.

Radiographic apex: Is the tip or the end of root determined radiographically.

Apical foramen: Is the region where the canal leaves the root surface next to the periodontal ligament. (American Association of Endodontists, 1984). It is the main apical opening of the root canal. It is frequently eccentrically located away from the anatomic or radiographic apex. Kuttler's investigation showed this deviation in 68 to 80 percent of the teeth. The anatomy of apical foramen changes with age (Figs 10.2A to C).

Accessory Foramen

Accessory foramen is an orifice on the surface of the root communicating with a lateral or accessory canal. They may exist as a single foramen or as multiple foramina.



Figs 10.2A to C: (A) The concept of the apex; (B) The apex of a younger person; (C) Changing apex due to hard tissue deposition

Apical Constriction (Minor diameter) (Figs 10.3 and 10.4)

It is the apical portion of the root canal having the narrowest diameter. The minor diameter widens apically to the foramen (major diameter) and assumes a funnel shape. The difference in length between the major and minor diameter will increase with age. The facts that point out that the longitudinal view of the canal, as a tapering funnel to the tip of the root is incorrect. The funnel tapers to a distance short of the site of exiting and widens again. Because the adjacent walls of cementum are slightly convex or hyperbolic when viewed in long section the configuration of the area between the major and minor diameter resembles that of a morning glory flower. "The morning glory flower configuration" is clearly visualized in an obturated radiograph when the sealer slightly extrudes past the apical constriction.

Although the apical constriction often is thought of as a simple constriction in the dentin. Dummer et al (1984) classified the apical constriction into four distinct types.

The tapering constriction would lead to under preparation and parallel constriction would lead to over preparation.

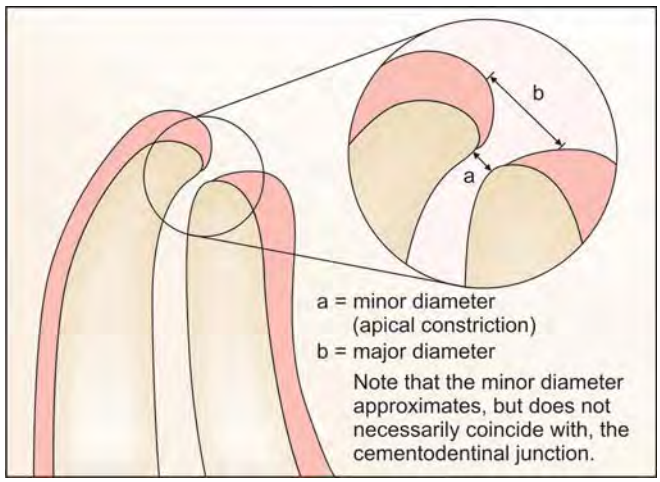


Fig. 10.3: Major and minor diameters

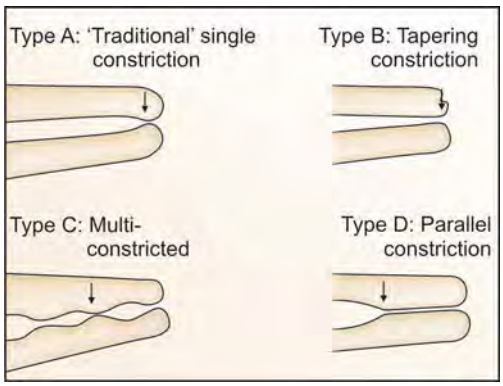


Fig. 10.4: Types of apical constrictions

The Cementodentinal Junction (CDJ): Is the region where the dentin and cementum are united, the point at which the cemental surface terminates at or near the apex of a tooth. The CDJ is a histological landmark and cannot be located radiographically or clinically.

Langeland reported that the CDJ does not always coincide with the apical constriction. Location of CDJ is 0.5 to 3.0 mm short of the anatomic apex while apical constriction is located 0.5 to 1.0 mm short of the radiographic apex. Due to variations, problems exist in locating apical landmarks and in interpreting their positions on radiographs.

Endometry: The term endometry refers to the accurate determination of the working length, which decides the apical termination point for all intracanal procedures from a reference point.

Levy and Glatt demonstrated that the apical foramen deviates from the root tip in atleast two-thirds of all teeth. This deviation occurs towards the buccal or lingual aspect twice often as it does towards the mesial or distal aspect. They advised use of taking angled radiograph in addition to the normal view for further information.

Use of Reference Points (Figs 10.5 and 10.6)

In anterior teeth the reference point is usually the incisal edge, but broken down teeth may be measured from adjustment teeth or from some projecting portion of the remaining tooth structure.

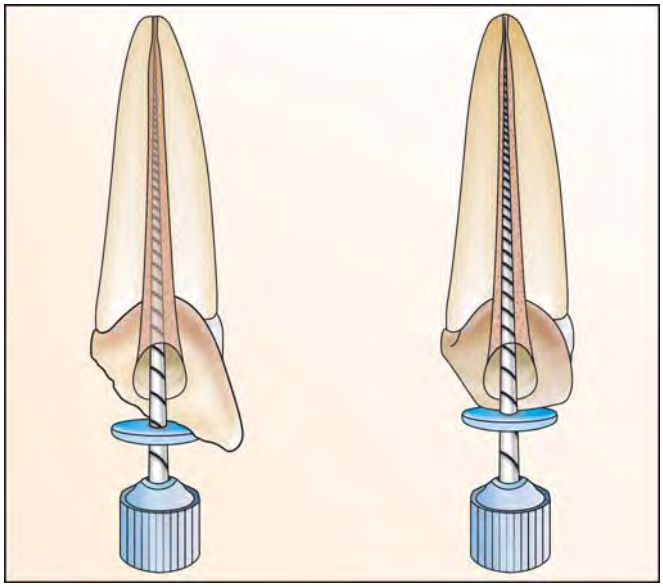


Fig. 10.5: Reference point

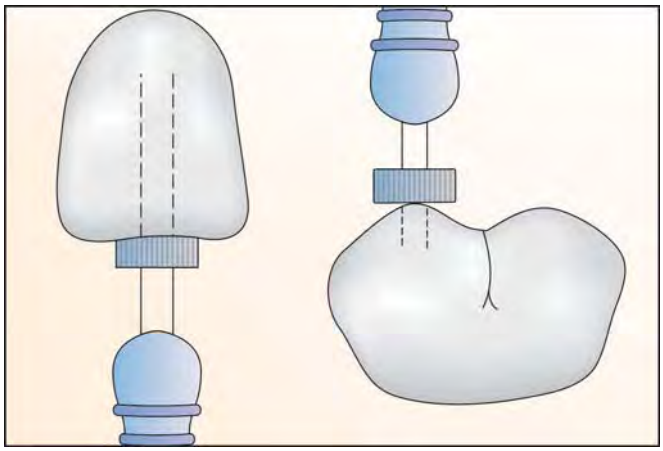


Fig. 10.6: Reference points

In bicanal bicuspid the buccal canal is generally measured to the buccal cusp tip, but the palatal canal may use either cusp tip as reference. There may be a variation of at least 1mm in length, depending on which reference point is used in measuring. In mandibular molars especially in mesial canals crossing of files frequently occurs. Mesiobuccal (MB) canal reference point may be mesiolingual (ML) cusp tip and ML canal reference point may be MB cusp tip. Similar mechanism some times used for maxillary molars also.

Stop attachments made up of metal, silicone rubber and plastic are available. Tear drop silicone-rubber stops have an added advantage because they do not have to be removed from the instrument during sterilization at 450°F and tear drop tip can be positioned to indicate instrumental curvature. The stop attachments should be perpendicular and not oblique to the shaft of the instrument. Length adjustments can be made against the edge of a sterile metric ruler. Rubber stops instruments have certain disadvantages like movement up or down the shaft, leading to measurements short or past the apical constriction.

Historical Perspectives

In the early days of endodontic treatment, at the end of the 19th century radiographs had not yet been applied to dentistry, and working length was usually calculated to the site where the patient experienced feeling for an instrument placed into the canal. This led to multiplicity of errors. If vital tissue were left in the canal unextirpated, the resulting calculation would be too short. If a periapical lesion were present, the calculation could be much too long. Teeth with more than one canal in a root could also give inaccurate information.

Then, with the advent of application of X-ray to dentistry by Kells in 1899, teeth treated without the benefit of radiographs, but evaluated by dental films, indicated these miscalculations, However, the introduction of a calculated working length, even though it still was in error at that time, was also a significant step in the acceptance of endodontic treatment in the early twentieth century.

In early 1900s, the popular opinion was that the dental pulp extended through the tooth, past the apical foramen into the periapical tissue, and that the narrowest diameter of the apical portion of the root canal was precisely at the site where the canal exits the tooth at the extreme apex. These views fostered then the prevailing technique to calculate to the tip of the root on the radiograph the radiographic apex - as the correct site to terminate canal preparation and till the canal. Thus, the radiograph apex replaced the response of the patient as the apical position for the calculation of working length.

In the 1920s, Grove concluded that pulp tissue could not extend beyond the CDJ because the cell unique to the dental pulp, the odontoblast, was not found past the CDJ.

Hatton and Grove advised that preparation beyond the CDJ would result in injury to periapical tissue.

Blayney and Coolidge Histological evaluations indicating that filling short of the root tip gave the best results.

In 1955, *Kuttler* Studied the microscopic anatomy of root tip, and decided that filing to the radiographic apex was an unwise clinical procedure, contributing to postoperative pain and lowering the production of successful cases. Hence, many decided to file specific distances away from the root tip in an effort to stop filing into the periapical tissues.

Some aspects of Kuttler's study have been questioned. The teeth that he studied had no caries, restorations or periapical lesions. These are hardly the type of teeth that are treated endodontically. However, many authors verified his anatomic descriptions of the root tip and agreed with his statistics.

Methods of Determining Working Length

The requirements of an ideal method for determining working length include rapid location of the apical constriction in all pulpal conditions and all canal contents; easy measurement, even when the relationship between the apical constriction and the radiographic apex is unusual; rapid periodic monitoring and confirmation; patient and clinician comfort; minimal radiation to the patient; ease of use in special patients such as those with severe gag reflex, reduced mouth opening, pregnancy etc., and cost effectiveness.

To achieve the highest degree of accuracy in working length determination, a combination of several methods should be used. This is important in canals for which working length determination is difficult.

The most common methods are:

i. Radiographic methods
ii. Electronic methods
iii. Audiometric method
iv. Digital tactile sense method
v. Paper point measurement
vi. Patient response

Radiographic Methods

- Grossman's method
- Ingle's technique
- Weine's modification
- Curved canals
- Other methods
  - Best method
  - Bregmen method
  - Bramante method
  - Everett and Fixot grid system
  - Euclidean endometry

Recent Advances in Radiographic Methods

- Radiovisiography(RVG)
- Xeroradiography
- Digital image processing
- Laser optical disk storage

RADIOGRAPHIC METHOD

Originally radiographic method was based on the tactile method. A file is introduced into the canal until the practitioner believes that the narrowest part of the root canal has been reached. The tooth is then radiographed. After processing, the relation between the tip of the instrument and the root apex is determined and the position of the file is changed accordingly. A new radiograph is taken if there is a significant difference.

Grossman's Method

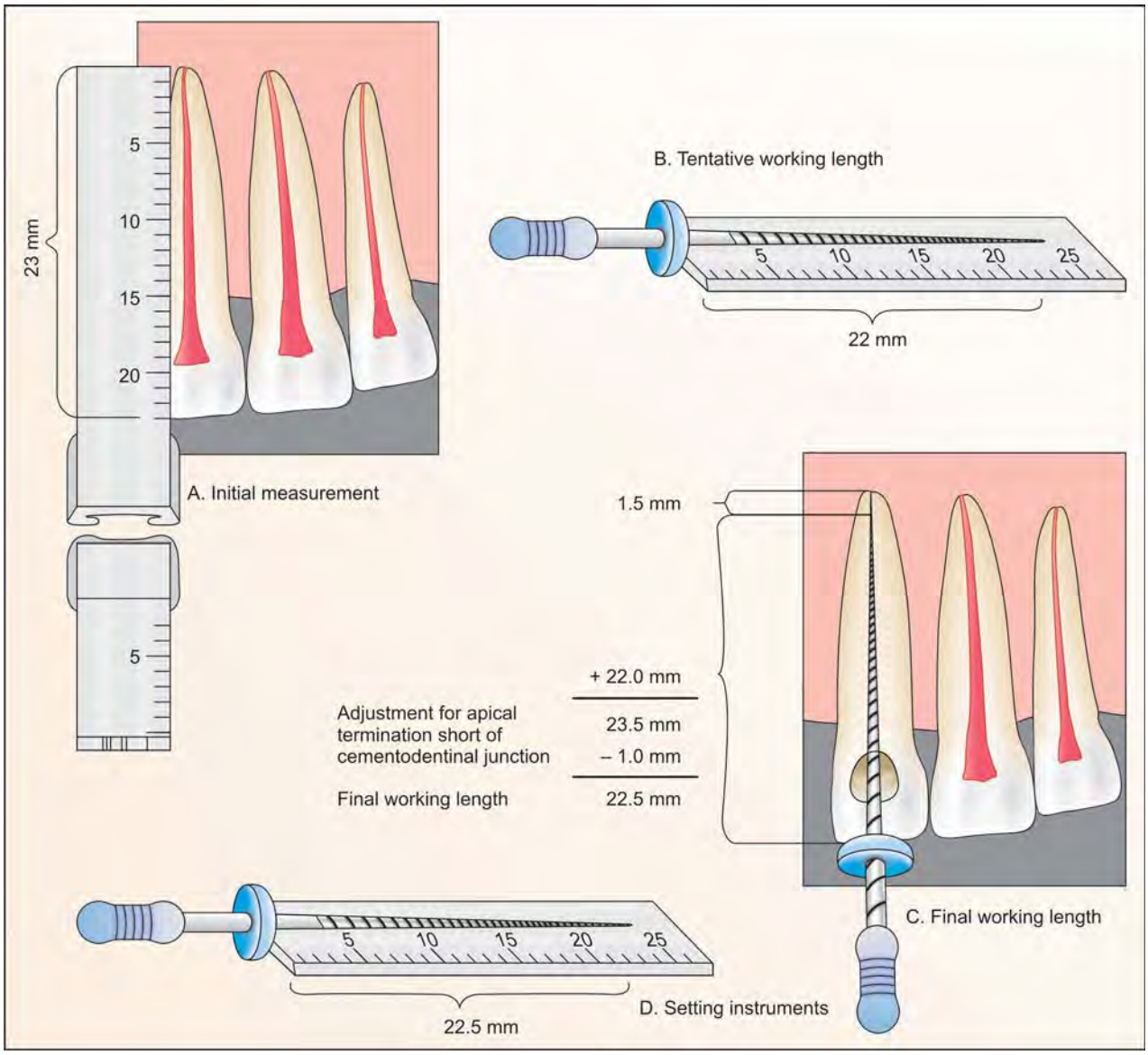
According to Grossman, an instrument extending to the apical constriction is placed in the root canal is determined by digital tactile sense and a radiograph is taken. A mark or stopper is placed at the occlusal or incisal reference point which will also be detectable on the radiograph. By measuring the length of radiographic images of both the tooth and measuring instrument as well as the actual length of the instrument the clinician can determine the actual length of the tooth by a mathematical formula.

$$\text{Actual length of tooth} = \frac{\text{Actual length of instrument} \times \text{Radiographic length of tooth}}{\text{Radiographic length of instrument}}$$

The disadvantage of this method is that even a small error will be multiplied.

Ingle's Technique (Figs 10.7A to D)

This method recommended by Ingle was reviewed by Bramante and Berbert who reported that this method is superior to other methods.



Figs 10.7A to D: (A) Initial measurement. The tooth is measured on a good preoperative radiograph using the long cone technique. In this case, the tooth appears to be 23 mm long on the radiograph; (B) Tentative working length. Subtract at least 1 mm from the initial measurement for a tentative working length of 22 mm. The instrument is set with a stop at this length; (C) Final working length. The instrument is inserted into the tooth to this length and a radiograph is taken. Radiograph shows that the image of the instrument appears to be 1.5 mm from the radiographic end of the root. This is added to the tentative working length, giving a total length of 23.5 mm. From this, subtract 1.0 mm as adjustment for apical termination short of the cementodentinal junction. The final working length is 22.5 mm; (D) Setting instruments. The final working length of 22.5 mm is used to set stops on instruments used to enlarge the root canal

Materials and Conditions

The following items are essential to perform this procedure:

1. Good, undistorted, preoperative radiographs showing the total length and all roots of the involved tooth.
2. Adequate coronal access to all canals.
3. An endodontic millimeter ruler.
4. Working knowledge of the average length of all of the teeth.
5. A definite, repeatable plane of references / anatomic landmark on the tooth - Should be noted on the patient's record.

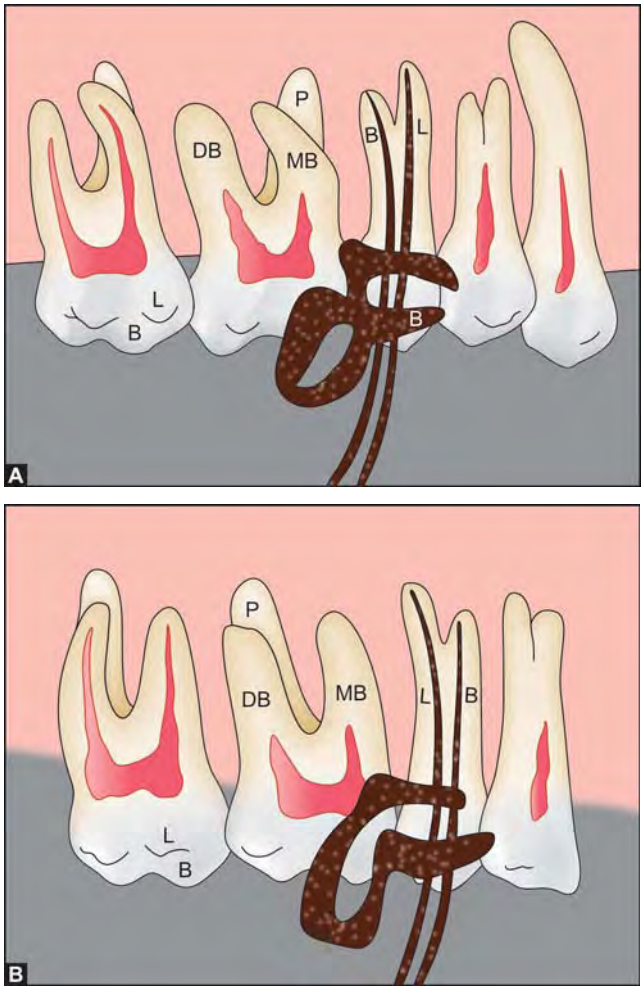
For intact or well restored teeth, the most common site for reference is the incisal edge of anterior teeth and the cusp height of posterior teeth. Teeth with fractured cusps or cusps severely weakened by caries restoration should be reduced to a flattened surface, supported by dentin. Failures to do so may result in weak cusps or weak enamel walls which can fracture between appointments. Thus if the original site of references is lost and left unobserved, there is the probability of over instrumentation and overfilling. In order to establish the length of the tooth, a stainless steel reamer or file with an instrument stop on the shaft is needed. The exploring instrument size must be small enough to negotiate the total length of the canal but large enough not to be loose in the canal. A loose instrument which may move in or out of the canal after the radiograph has been taken can cause serious error in determining the length of the tooth. In curved canals, pre-curved instrument or nickel-titanium instruments are preferred.

Method

1. *Initial measurement:* The tooth length is measured on a good preoperative radiograph.
   Example: The length is 23 mm.
2. *Tentative working length:* As a safety factor, allowing for image distortion or magnification subtract at least 1mm from the initial measurement for a tentative working length of 22 mm. The instrument is set with a stop at this length.
3. *Final working length:* The instrument is inserted into the tooth to this length and a radiograph is taken. Radiograph shows that the image of the instrument appears to be 1.5 mm from the radiographic end of the root. This is added to the tentative working length giving a total length or 23.5 mm form this subtract 1.0 mm is adjustment for apical termination short of the cementodentinal junction (CDJ). The final working length is 22.5 mm.
4. *Setting instruments:* The final working length 22.5 mm is used to set stops on instruments used to enlarge the root canal.

The Ingle method produced the smallest variability in the determination of tooth length and the greatest percentage of successful measurements.

However, there are many reports showing variations in the position of the apical foramen. When the two canals of a maxillary first premolar appear to be superimposed,



Figs 10.8A and B: SLOB Rule: (A) Cone moved to mesial; (B) Cone moved to distal

then the preferable method is to expose the radiograph from a mesial horizontal angle when the X-ray beam is directed from the mesial, the buccal canal is projected toward the distal on the film and palatal canal on mesial side on the film. Same with lower molar mesial canals (SLOB rule or Clark's rule) (Figs 10.8A and B).

Accuracy

How accurate is the radiographic method depends upon the radiographic technique used. *Forsberg* demonstrated that paralleling technique was more reliable than the bisecting angle technique.

Olso et al pointed out 82-89 percent accuracy with radiographs. Hence, they recommended the use of other methods like tactile feel or electronic apex locators as well.

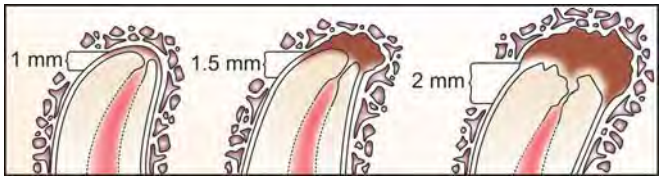


Fig. 10.9: Weine's modification

A British group recommended the use of radiovisiography with image enhancement to improve the quality of working length radiographs.

Weine's Modification (Fig. 10.9)

Weine's recommendations for determining working length are based on radiographic evidence of root / bone resorption.

1. If no root or bone resorption is evident preparation should terminate 1.0 mm from the apical foramen.
2. If bone resorption is apparent but there is no root resorption shorten the length by 1.5 mm
3. If both root and bone resorption is apparent shorten the length by 2.0 mm.

Curved Canals

Even though accurately determined and confirmed, the final working length may shorten as curved canals are enlarged. Since "a straight line is the shortest distance between two points" the final working length may shorten by as much as 1mm as the curved canal is straightened out by instrumentation. So the length should be reconfirmed after instrumentation is completed. The use of pre-curved files and Nickel Titanium files in curved canals are the best method to complete the endodontic treatment.

Other Methods

Various methods have been suggested to determine working length. They differ only as regards technique and complexity, with the result some of them are used more than others. Among the methods commonly employed in endodontics, those of Best, Bregmen and Bramante are the used methods. What are the advantages presented by these methods? And which is more precise? These questions have not been answered in the literature. Each author has proclaimed his technique to be the best.

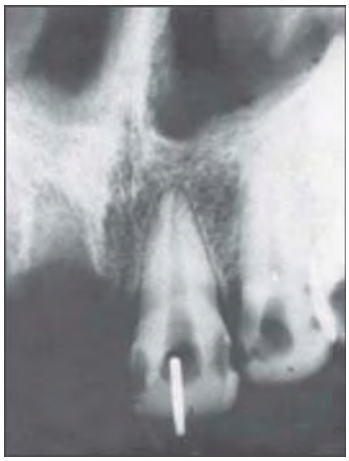


Fig. 10.10: Best method

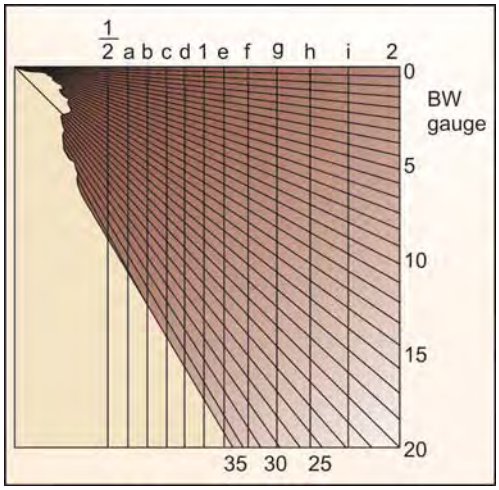


Fig. 10.11: BW gauge
(*Courtesy:* Star Dental Manufacturing Co INC Philadelphia, 39, P4, USA)

Best Method (Figs 10.10 and 10.11)

In this method, as described by Best: A 10-mm steel pin was fixed to the labial surface of the tooth with utility wax in a position parallel to its long axis before radiograph was obtained. The radiograph so obtained was carried to the BW gauge which indicates the tooth length.

Best attained little success, generally resulting in lengths greater than the real length of the teeth.

Bregman Method (Figs 10.12 and 10.13)

In this method flat probes, 25 mm in length, were prepared. Each had a steel blade fixed with acrylic

Fig. 10.12: Bregman probe

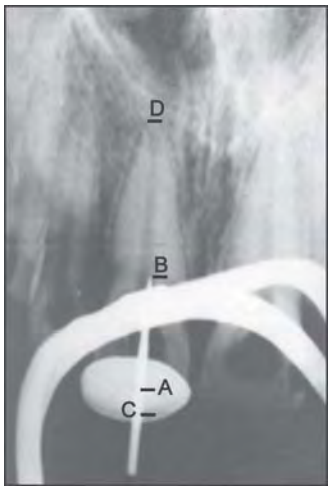


Fig. 10.13: Bregman method

resin as a stop, leaving a free segment of 10 mm for placement into the root canal. This probe was placed in the tooth until the metallic end touched the incisal edge or cusp tip of the tooth. Then a radiograph was taken. In the radiographic image the following factors were measured:

CAD = Apparent tooth length, seen in the radiograph.
CRI = Real instrument length.
CAI = Apparent instrument length, seen in the radiograph.

To these factors the following formula was applied: The real tooth length is CRD:

$$CRD = \frac{CRI \times CAD}{CAI}$$

In this method Bregman did not indicate the point to be taken as reference for measurements in the coronal portion. Not only the incisal edge or the cusp tip but also the visible mark of the probe appears radiographically in different planes. In molar teeth, with the superimpositions of the radiographic images of the cusps, it is difficult to make the measurement precisely. The percentage of success obtained with this method is low because of its high variability which showed the length sometimes to be greater and some times smaller.

Bramante Method (Fig. 10.14)

Bramante, in 1970, presented a method to determine the tooth length, employing stainless steel probes of various calibers and lengths. These were bent at one end, forming a right angle, and this bend was inserted partially in acrylic resin, in such manner that its internal face was flush with the resin surface contacting the tooth surface. The probe was introduced into the root canal so that the resin touched the incisal edge or cusp tip, taking care to see that the bent segment of the probe would be parallel to the mesiodistal diameter of the tooth crown, thus making it possible to visualize it on the radiograph. Then the tooth was radiographed.

In this radiograph, the reference points are as follows:

A = Internal angle of intersection of the incisal and radicular probe segments.
B = Apical end of the probe.
C = Tooth apex.

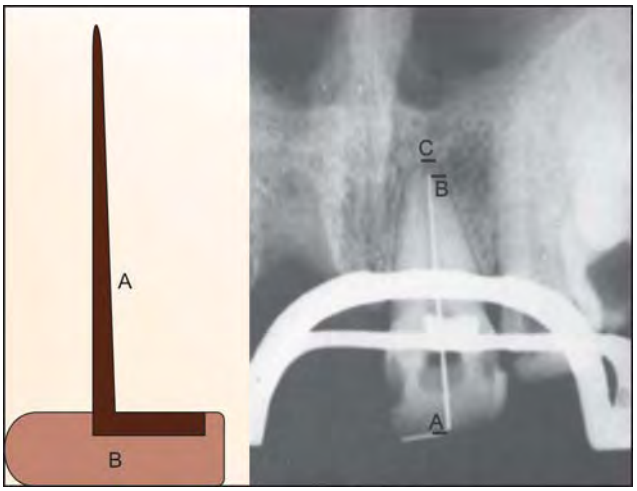


Fig. 10.14: Bramante method

The tooth length was calculated in two different ways.

1. Measuring the radiographic image length of the probe A to B; measuring the radiographic image length of the tooth from A to C; measuring the real length of the probe. To these data, the following equation may be applied:

$$CRD = \frac{CRS \times CAD}{CAS}$$

Where

CRD = Real tooth length
CRS = Real probe length
CAD = Tooth length in the radiograph
CAS = Probe length in the radiograph.

This method is a variation that follows the principles of the Bregmen method.

2. Measuring the distance between the apical end of the probe (B) and the tooth apex (C) in the radiograph, adding or diminishing this measurement of the real length of the probe, in this way obtaining the tooth length.

This method is a variation that follows the principles of the Ingle method.

Grid System (Fig. 10.15)

Everett and Fixot (1963) designed an X-ray grid system for determining the length of the tooth. The grid designed consists of lines 1 mm apart running length-wise and cross-wise. Every fifth mm is accentuated by a heavier line to make reading easier on the radiograph. Enameled copper wire is placed into Plexiglas and fixed to regular periapical film. The grid is taped to the film to lie between the tooth and film during exposure so that the pattern becomes incorporated in the finished film. The tooth length determined by this method is more accurate than by other methods.

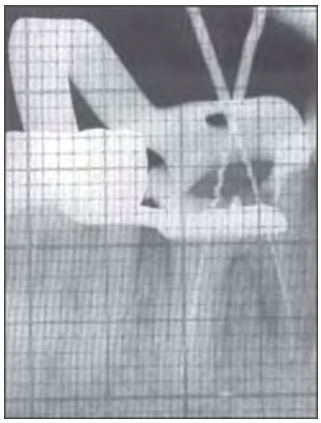


Fig. 10.15: Grid method

Euclidean Endometry

An extra canal length determination method called Euclidean endometry was developed. This uses two geometrically distorted radiographs in determining the real length of the tooth. The two radiographs are taken with a cone fitted with an "Updegraves XCP" (Extension cone paralleling method) device at two different vertical angulations. The actual tooth length is calculated by geometrical principles from the length of the tooth in the two radiographs and the known verticular angular differences.

Disadvantages of radiographic methods:

1. Anatomic structures and radiopaque materials may be super imposed on the image of the root.
2. The biologic risk of radiation.
3. The procedure is time consuming.
4. Radiograph is a two dimensional representation of a three dimensional object.
5. The apical foramen could not be correctly identified because it frequently deviated from the anatomic apex.
6. Patient with gag reflex or limited mouth opening may inhibit taking radiographs.

Recent investigations tend to show that the radiograph technique of tooth length determination is less accurate than was previously believed.

Chunn et al found that a file introduced into a root canal overextended the root tip in 33 percent of the cases with the bisecting angle technique and over extended in 20 percent using paralleling technique.

Recent Advances in Radiographic Methods

1. Radio visiography (RVG)
2. Xeroradiography
3. Digital image processing
4. Laser optical disk storage

Determination of Working Length by Audiometric Method

This method was introduced by Inoue in 1985. The audiometric method, a variation on the principle of

electrical resistance of comparative tissue, uses low frequency oscillation sound to indicate when similarity to electric resistance has occurred by a similar sound response. By placing an instrument in the gingival sulcus and inducing an electric current until sound is produced, and then repeating this by placing an instrument through the root canal until the same sound is heard, one can determine the length of the tooth. This principle was utilized in electronic measurements as an audible component.

Detection of Working Length by Paper Points

In a root canal with an immature apex, the most reliable means of determining working length is to gently pass the blunt end of a paper point into the canal after profound anesthesia has been achieved. The moisture or blood on the portion on the portion of the paper point that passes beyond the apex may be an estimation of working length or the junction between the root apex and the PDL. In cases in which the apical constriction has been lost owing to resorption or perforation, and in which there is no free bleeding or suppuration into the canal, the moisture or blood on the paper point is an estimate of the amount the preparation is overextended. This method is a supplementary one.

A new dimension has recently been added to paper points by the addition of millimeter markings. These paper points have markings at 18, 19, 20, 22 and 24 mm from the tip and can be used to estimate the point at which the paper point passes out of the apex. These paper points were designed to ensure that they can be inserted fully to the apical constriction. The accuracy of these markings should be checked on a millimeter ruler.

Detection of Working Length by Patient Response

Another fallacious belief is that if the pulp is necrotic or if canal preparation is complete, an unanesthetized patient will detect the file tip when it reaches and contacts the vital tissue at the apical foramen. The patient then signals this event with an "eye blink" or other pain response. There are certain problems with this approach. First, the procedure is painful for the patient. Second, a necrotic pulp frequently contains vital inflamed tissue that extends several millimeters into the canal. This tissue may be very sensitive and respond to instrument contact short of the apex. Third, a patient feels pain after canal preparation is complete from hydraulic pressure even though instruments do not reach the apical region.

The opposite of pain with instruments short of length is lack of pain response when instruments are beyond the apex. This has been observed in some situations when, in an unanesthetized patient, instruments have passed several millimeter out of the apex without being detected.

APEX LOCATORS

One of the innovations in root canal treatment has been the development and production of electronic devices for detecting the canal terminus. Their functionality is based on the fact that the electrical conductivity of the tissues surrounding the apex of the root is greater than the conductivity inside the root canal system provided, the canal is either dry or filled with a nonconductive fluid (Custer 1918).

Suzuki (1942) indicated that the electrical resistance between a root canal instrument inserted into a canal and an electrode applied to the oral mucous membrane registered consistent values. Based on these findings, Sunada (1962) reported that when the tip of an endodontic instrument had reached the periodontal membrane through the “apical foramen”, the electrical resistance between the instrument and the oral mucous membrane was a constant value. Based on this fundamental principle, these resistance-based devices should be able to detect the periodontal tissue at the “apical foramen”.

Clearly, these devices do not assess the position of the root apex and the name “electronic apex locator” is not appropriate; “electronic apical foramen locator” or “Electronic Root Canal Length Measurement Device” (ERCLMD) as a generic name would be more appropriate.

Mode of Action (Fig. 10.16)

When the tip of an endodontic instrument reaches the periodontal membrane through the 'apical foramen', the electrical resistance between the instrument and the oral mucous membrane is a constant value.

All the apex locators function by using the human body to complete an electrical circuit. One side of the apex locator's circuit is connected to an endodontic

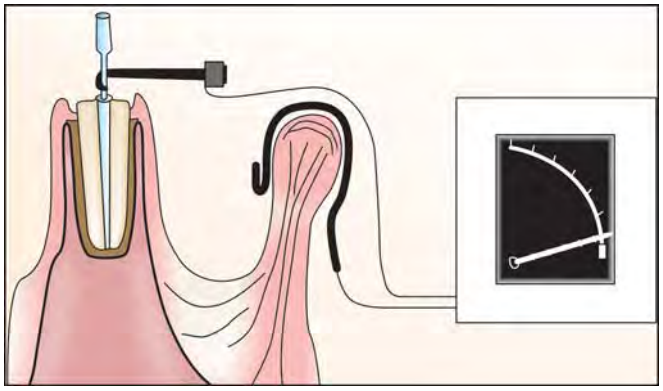


Fig. 10.16: Diagrammatic representation of principle of apex locators

instrument and the other side is connected to patient`s lip or by an electrode held in the patient's hand. The electrical circuit is complete when the endodontic instrument is advanced apically inside the root, until it touches periodontal tissue. The display on the apex locator indicates that the apical area has been reached.

Classification of Apex Locators

This classification is the modification of the McDonald classification. The classification is based on the type of current flow and the opposition to the current flow as well as number of frequencies involved.

First Generation

These devices are also known as "Resistance apex locators". The Root Canal Meter (Onuki Medical Co., Tokyo, Japan) was developed in 1969. It used the resistance method and current as a 150-Hz sine wave. Pain was often felt due to high currents in the original machine, so improvements were made and released as the Endodontic Meter and the Endodontic Meter S II (Onuki Medical Co.) which used a current of less than 5 A (Kobayashi 1995).

Principle

When the tip of the reamer reaches the apex in the canal, the resistance value is 6.5 kilo ohms (Electric Current - 40 mA). Resistance-based apex locators have been shown to be accurate in dry conditions within the canal. The original device was reported to be most accurate in palatal canals of maxillary molars and premolars.

Types of Apex Locators

Category	*Name*	*Manufacturer*
Resistance based	Endodontic meter	Parkell Inc , USA
	Endometer	Parkell Inc , USA
	Foramatron 4	Parkell Inc , USA
	Apex finder	Parkell Inc , USA
Low frequency oscillation	Sono-explorer	Hayashi dental supply, Japan
	Sono-explorer mark II	Hayashi dental supply, Japan
Capacitance based (High frequency) devices	Endocator	Hygienic corporation, USA
Capacitance and resistance	Elements diagnostic unit	Sybron endo, USA
Two frequency, Impedance difference	Apit	Osada Tokyo, Japan
	Apex pointer	Micro mega, France
Impedance ratio	Justy II	Parkell Inc , USA
	Endy 5000	Parkell Inc , USA
	Root ZX	J Morita, Japan
Multi frequency	Endo analyzer (8005)	Sybron endo, USA
	AFA apex finder (7005)	Sybron endo, USA
Unknown	Foramatron D 10	

Disadvantage

These were not always accurate in presence of pus, strong electrolytes, hemorrhage, and pulp tissue.

Sono Explorer

It was imported from Japan by Amadent. Today most of the first generation apex locators are off the market.

Second Generation

Second generation apex locators are known as "impedance" apex locators. Impedance is comprised of resistance and capacitance and has a sinusoidal amplitude trace. The property is utilized to measure distance in different canal conditions by using different frequencies.

The change in frequency method of measuring was developed by Inoue in 1971 as the Sono-Explorer (Hayashi Dental Supply, Tokyo, Japan) which calibrated at the periodontal pocket of each tooth and

measured by the feedback of the oscillator loop (Inoue 1972). The beeping of the device indicated apical limit, so some clinicians erroneously thought that it measured by using sound waves (Inoue 1973).

Principle

It measures the opposition of flow to alternating current, or Impedance.

Different Types

i. Sono explorer II:
   - It is one of the earliest of the second generation apex locators.
   - Later a number of improvements were available in the sono explorer.

ii. The Apex finder:
   - It has a visual digital LED indicator and is self-calibrating.
   - Compared to radiographic working length estimations, placed the accuracy at 67 percent (0.5 mm from radiographic apex).

iii. Endo analyzer:
   - It is a combined apex locator and pulp tester.

iv. Digipex:
   - It has a visual LED digital indicator and an audible indicator.
   - It requires calibration.

v. Digipex II:
   - It is a combination of the apex locator and pulp vitality tester.

vi. Exact-A-Pex: (Ellman international)
   - It has a LED bar graph display and an audio indicator.
   - An *in vitro* study reported an accuracy of 55 percent (0.5 mm from apex).

vii. Formatron IV : (Parkell dental)
   - It has a flashing LED light and digital LED display.
   - It does not require calibrations.
   - Electronic determinations found to be accurate in 65 percent of the cases.

viii. The PIO apex locator:
   - It has an analog meter display and an audio indicator.
   - It has an adjusting knob for calibrations.

The most important disadvantage of second generation devices was the need for individual calibration which was done by correlation of gingival crevice sound'.

Third Generation

These devices are frequency dependent.

Principle

These instruments use multiple frequencies to determine the distance from the end of the canal. These units have powerful microprocessors and are able to process the mathematical quotient and algorithm calculations required to give accurate readings.

In biological settings, the reactive component facilitates the flow of alternating current more for higher than for lower frequencies. Thus, a tissue through which two alternating currents of differing frequencies are flowing will "impede" the lower frequency current more than the higher frequency current. The reactive component of the circuit may change as the position of a file changes in a canal. When this occurs, the impedances offered by the circuit to currents of differing frequencies will change relative to each other.

Since it is impedance, not frequency that is measured by these devices and since the relative magnitudes of the impedances are converted into "length information" the term "comparative impedance" may be appropriate.

Different types are:

i. *Endex (Apit) (Figs 10.17A and B):* The original third generation apex locator, was described by Yamaoka et al.

Principle

It uses a very low alternating current. The signals of two frequencies (5 and 1 kHz) are applied as a composite waveform of both frequencies. As the attached endodontic reamer enters the coronal part of the canal, the difference in the impedances at the two frequencies is small. As the instrument is advanced apically, the difference in impedance values begins to change. As the apical constriction is reached, the impedance values are at their maximum difference and these differences are indicated on the analog meter and audio alarm. This impedance difference is the basis of the difference method. The unit must then be reset for each canal.

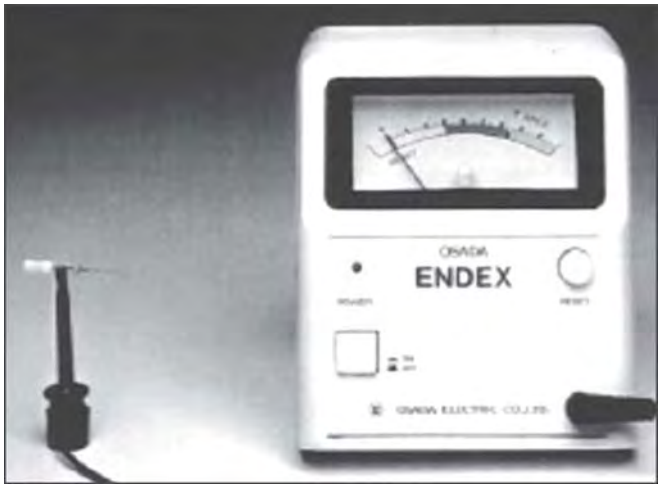


Fig. 10.17A: Endex apex locator

Fig. 10.17B: Endex plus apex locator

Gutta-percha must be removed from the canals in retreatment cases before working length determination is made.

Advantages

- The device operates most accurately when the canal is filled with electrolyte.
- The manufacturer indicates that the size of the endodontic instrument does not affect the measurement.
- Endex was superior to second generation devices when there was conductive fluid in the canals and when the apical foramen was wide.
- It could be used to determine working length under various conditions such as bleeding, exudate and hypochlorite in the canals.
- Accuracy was 96.5 percent (0.5 - 0.0 mm from apex).

Fig. 10.18: Neosono Ultima Ez apex locator

ii. *Neosono Ultima Ez apex locator (Fig. 10.18):*
- It is the third generation device that supersedes the second generation sono-explorer line.
- Two alternating current frequencies are used with a microchip that sorts out two of the many frequencies to give an accurate reading in either wet or dry canals.
- The ultima Ez is mounted with a root canal graphic showing file position as well as an audible signal.
- In the canals with open apices the digital readout is subtracted by 0.5 or 1.0 mm to get the correct working length.
- It works best in the presence of sodium hypochlorite.

iii. *The Justwo or Justy-II (Fig. 10.19):*
- This is another third generation apex locator.
- It uses frequencies of 500-2000 Hz in a relative value method. Two potentials are obtained that correspond to two impedances of the root canal. These two potentials are converted into logarithmic values and one is subtracted from the other. The result drives the meter. The rationale of Just-II resembles Root Zx.

Fig. 10.19: Justwo

Fig. 10.20: Mark V plus

- The analog meter and audio indicator display the position of the instrument tip inside the canal.
- The unit determines the working length in the presence of electrolytes.

iv. *Mark V plus (Fig. 10.20):*
- It is identical in circuitry and performance to Ultima Ez.

v. *Co-pilot:*
- The co-pilot is the Ultima Ez with the attached pulp tester.
- It is said to be more reliable in wet canals than in dry.
- It is also "quick and easy" to use.

Fig. 10.21: Apex finder AFA

vi. *Apex finder AFA (all fluids allowed) (Fig. 10.21):*
- It uses Multiple Frequencies and Comparative Impedance principle in its electronic circuit. Gives accurate readings regardless of irrigants or fluids in the canals being measured.
- It has a an audio indicator and liquid crystals display (LCD) panel that indicates the distance of the instrument tip from apical foramen in 0.1 mm increments.
- The display has a bar graph canal condition indicator that reflects canal wetness / dryness that allows the user to improve canal conditions for working length determination.
- This device was able to locate the cemento-dentinal junction or a point 0.5 mm coronal to it with 95 percent accuracy.

vii. *Endo analyzer 8005 (Fig. 10.22):* It combines apex location and pulp tester in one unit. The Endo Analyzer 8005 features two self-calibrating apex location programs that utilize five frequencies with graphical display of the apical foramen in 0.1-mm increments as well as an audible chime when the foramen is reached.

viii. *Root Zx (Fig. 10.23):* The Root-Zx is mainly based on detecting the change in the electrical capacitance that occurs near the apical constriction.

Principle

- This device uses dual frequencies and comparative impedance principles.
- The electronic method employed was the "ratio method" or "division method".

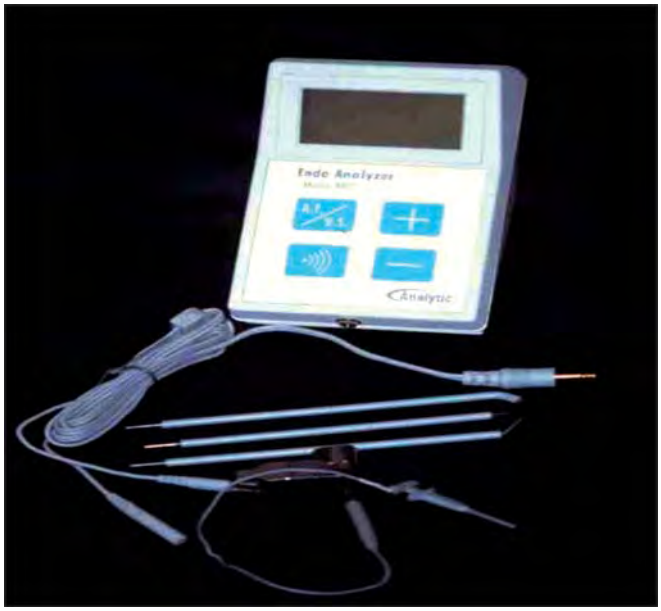


Fig. 10.22: Endo analyzer 8005

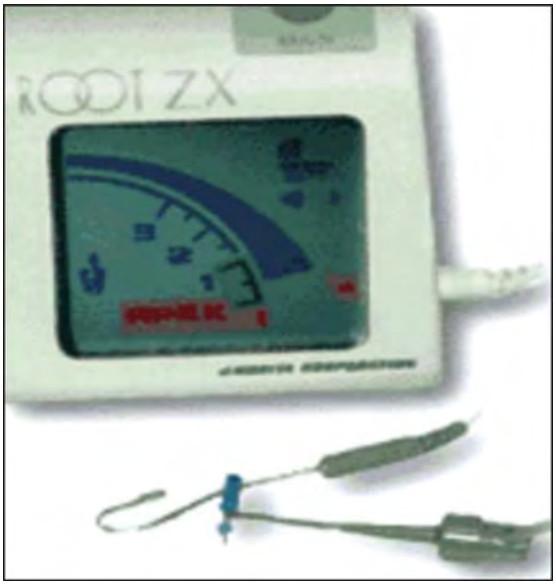


Fig. 10.23: Root Zx

- It simultaneously measures the two impedances at two frequencies (8 and 0.4 kHz) inside the canal.
- A microprocessor in the device calculates the ratio of the two impedances. The quotient of impedances is displayed on an LCD meter panel and represents the position of instrument tip inside the canal. The quotient was hardly influenced by the electrical conditions of the canal but changed considerably near the apical foramen.

Advantages

- It requires no adjustments or calibration and can be used when canals are filled with strong electrolyte or when canal is empty and moist.
- The meter is an easy to read LCD.
- The position of instrument tip inside the canal is indicated on the LCD meter and by the monitor's audible signals.
- It allows shaping and cleaning of root canal with simultaneous, continuous monitoring of working length.
- Accuracy for the device ranged from 84 to 100 percent (0.5 mm for apex).

Disadvantages

The display shows a relative scale and does not indicate absolute intracanal distances from the apical constriction.

Recommendations

Correct working length is calculated by subtracting 0.5 to 1.0 mm from working length indicated by the reading on the meter.

Root Zx should be used with 0.0 or "Apex" increment mark as the most accurate apical reference point. The clinician should then adjust the working length on the endodontic instrument for the margin of safety that is desired.

ix. *Tri auto Zx (Fig. 10.24):*
- It is the combination of apex locator and endodontic hand piece.

Fig. 10.24: Tri auto Zx

- It is a cordless electric endodontic hand piece with a built in Root Zx apex locator.

Mode of Action

The hand piece uses Ni-Ti rotary instruments that rotate 280 50 rpm. The position of the tip of the rotary instrument is continuously monitored on the LED control panel of the handpiece during the shaping and cleaning of the canal.

The Tri auto Zx has three automatic safety mechanisms.

a. Auto start-stop mechanism:
   The handpiece automatically starts rotation when the instrument enters the canal and stops when the instrument is removed.
b. Auto-torque-reverse mechanism
c. Auto-apical-reverse mechanism:

The handpiece automatically stops and reverses rotation when the instrument tip reaches a distance from the apical constriction that has been preset by the clinician. This prevents instrument beyond the apical constriction.

The Tri auto Zx has four modes:

1. Electronic measurement of root mode (EMR): A lip clip, hand file and file holder are used with apex locator in handpiece to determine the working length. The handpiece motor does not work in this mode.
2. Low mode: The torque threshold was lower than high mode. The low mode is used with small to mid sized instruments for shaping and cleaning the apical and mid-third sections of root canal. All three automatic safety mechanisms are functional in this mode.
3. High mode: The torque threshold is higher than low mode. The high mode is used with mid sized to large instruments for shaping and cleaning in the mid third and coronal third sections of the root canal. All three automatic safety mechanisms are functional in this mode.
4. Manual mode: This offers highest threshold of torque. The auto-start stop and auto-torque-reverse mechanisms do not function. The auto-apical reverse mechanism does function. This mode is used generally with large instruments for coronal flaring.

x. *Endy 7000:*

It is an endodontic handpiece connected to an Endy apex locator marketed in Europe.

It reverses the rotation of the endodontic instrument when it reaches a point in the apical region preset by the clinician.

xi. *Safy Zx:*

It is the new development of ultrasonic systems. It is a handpiece along with apex locator. (Kobayashi)

It uses the Root Zx to electronically monitor the location of the file tip during all instrumentation procedures.

The device minimizes the danger of over instrumentation.

The Fourth Generation

Bingo-1020/RAYPEX-4/ RAYPEX-5 (Figs 10.25 and 10.26)

The Bingo 1020 (Forum engineering technologies, Rishon Lezion, Israel) claims to be a fourth generation device and the unit uses two separate frequencies 0.4 and 8 kHz similar to the current third generation units. The manufacturers claim that the combination of using only one frequency at a time and basing measurements on the root mean square (rms) values of the signals increases the measurement accuracy and the reliability of the device.

An in vitro study of the Bingo 1020 found it to be as reliable as the Root ZX and also user friendly (Kaufman et al 2002). Tinaz et al (2002a) found the Bingo 1020 to be as accurate as the Root ZX in an

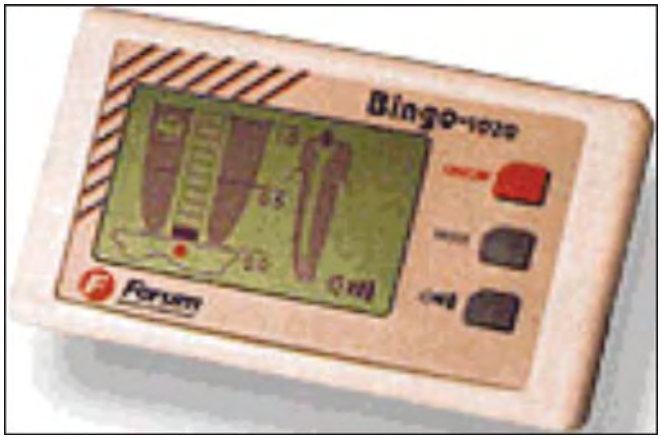


Fig. 10.25: Bingo-1020

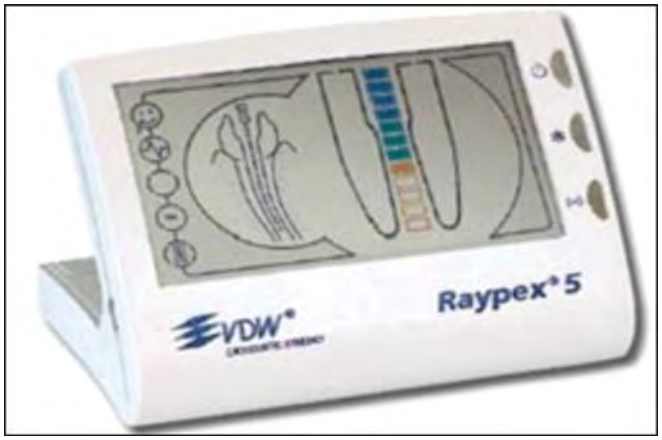


Fig. 10.26: Raypex-5

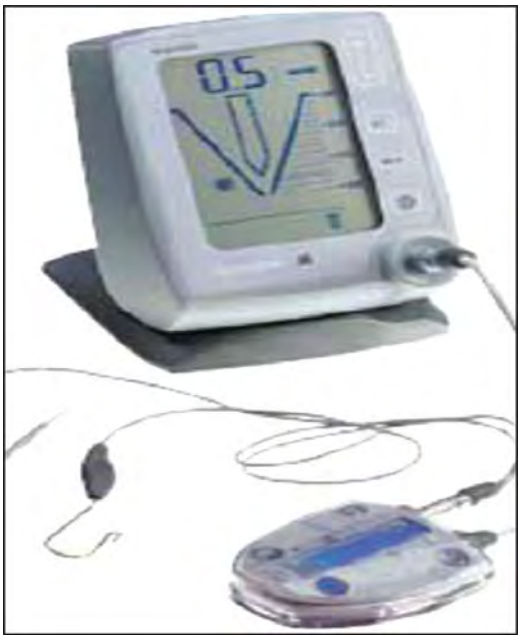


Fig. 10.27: Elements diagnostic unit and apex locator

in vitro study and easier for a beginner to use in preflared canals. A similar unit has subsequently been marketed by Dentsply as the Raypex-4/5.

A new unit to the market in 2003 is the Elements diagnostic unit and apex locator (Fig. 10.27) (Sybronendo, Anaheim, CA, USA). The device does not proceed the impedance information as a mathematical algorithm, but instead takes the resistance and capacitance measurements and compares them with a database to determine the distance to the apex of the root canal (Lively 2003, personal communication). It uses a composite waveform of two signals 0.5 and 4 kHz. The signals go through a digital-to-analog converter to be converted into an analog signal, which then goes through amplification and then to the patient circuit model which is assumed to be a resistor and capacitor in parallel. The feedback signal waveforms are then fed into a noise reduction circuit.

The manufacturer claims that this allows less sampling error per measurement and more consistent readings.

Effect of Different Metal Types

The question whether which type of metal be used. Nekoofar et al evaluated the accuracy of Neosono Ultima EZ with nickel titanium and stainless steel files. And accuracy of Ni-Ti was 94 percent and stainless files was 92 percent there was no statistically significant difference.

Other uses of Apex Locators

- It can be used to detect root perforations and pulpal floor perforations.
- It helps in diagnosis of external resorption that has invaded the dental pulp space or internal resorption that has perforated to the external root surface.
- Prepared pinholes can be checked to detect perforations into pulp or periodontal ligament.
- Horizontal or vertical root fractures can also be detected as well as post perforations.
- Used in endodontic treatment of teeth with incomplete root formation.

Contraindications of EALs

The use of apex locators and other electrical devices such as pulp tester and electrosurgical instruments are contraindicated for patients who have cardiac pacemakers. Electrical stimulation to the patient`s pacemaker can interfere with pacemaker function. In special cases, an apex locator may be used on a patient with a pacemaker when it is done in consultation with the patient's cardiologist.

Clinical Acceptance

Use of the electronic apex locator to determine working length has still not gained widespread acceptance worldwide. This may in part be due to early devices which suffered from poor accuracy and

did not function properly in the presence of common irrigants. Cost of the instruments and exposure to the technology are also significant factors.

The Future for Electronic Apex Locators

The future of apex locators is promising. Significant improvement in the reliability and accuracy of apex locators has taken place with the development of newer models. However, studies have not conclusively demonstrated if apex locators are superior to radiographic techniques, nor can they routinely replace radiographs in working length determination. It has been demonstrated that they are at least equally accurate. Future apex locators should be able to determine working length in all electronic conditions of the root canal without calibration. The meter display on future apex locators may accurately indicate how many millimeters the endodontic tip is from the apical constriction.

CONCLUSION

No individual technique is truly satisfactory in determining endodontic working length. The CDJ is a practical and anatomic termination point for the preparation and obturation of the root canal and this cannot be determined radiographically. Modern electronic apex locators can determine this position with accuracies of greater than 90 percent but still have some limitations. Knowledge of apical anatomy, prudent use of radiographs and the correct use of an electronic apex locator will assist practitioners to achieve predictable results.

SUGGESTED READING

1. Azabal M, Garcia-Otero D, de la Macorra JC. Accuracy of the Justy II apex locator in determining working length in simulated horizontal and vertical fractures. International Endodontic Journal 2004;37:174-77.
2. Beach CW, Bramwell JD, Hutter JW. Use of an electronic apex locator on a cardiac pacemaker patient. Journal of Endodontics 1996;22:182-84.
3. Berman LH, Fleischman SB. Evaluation of the accuracy of the Neosono-D electronic apex locator. Journal of Endodontics 1984;10:164-67.
4. Blaskovic-Subat V, Maricic B, Sutalo J. Asymmetry of the root canal foramen. International Endodontic Journal 1992;25:158-64.
5. Czerw RJ, Fulkerson MS, Donnelly JC, Walmann JO. In vitro evaluation of the accuracy of several electronic apex locators. Journal of Endodontics 1995;21:572-75.
6. Determining theoptimal obturation length: a meta-analysis of the literature.Journal of Endodontics 31:271-74.
7. Dummer PMH, McGinn JH, Rees DG. The position and topography of the apical canal constriction and apical foramen. International Endodontic Journal 1984;17: 192-98.
8. ElAyouti A, Weiger R, Lo¨st C. The ability of root ZX apexlocator to reduce the frequency of overestimated radiographic working length. Journal of Endodontics 2002;28:116-19.
9. Euiseong Kim, Seung-Jong Lee, Electronic apex locators. Dent Clin N Am 2004;48:35-54.
10. Frank AL, Torabinejad M. An in vivo evaluation of Endexelectronic apex locator. Journal of Endodontics 1993;19:177-79.
11. Schaeffer M, White R, Walton R. Determining the optimal obturation length: a meta-analysis of the literature. Journal of Endodontics 2005;31:271-74.
12. Gordon MPJ, Chandler NP. Electronic apex locators. International Endodontic Journal 2004;37:1-13.
13. Katz A, Tamse A, Kaufman AY. Tooth length determination: a review. Oral Surgery, Oral Medicine, and Oral Pathology 1991;72:238-42.
14. Martinez-Lozano M, Forner-Navarro L, Sanchez-Cortes J, Llena-Puy C. Methodological considerations in the determination of working length. International Endodontic Journal 2001;34:371-76.
15. MH Nekoofar1, MM. Ghandi, SJ Hayes, PMH Dummer. The fundamental operating principles of electronicroot canal length measurement devices International Endodontic Journal 2006;39:595-609.
16. Ricucci D. Apical limit of root canal instrumentation and obturation, part 1. Literature review. International Endodontic Journal 1998;31:384-93.
17. Welk AR, Baumgartner JC, Marshall JG. An in vivo comparison of two frequency-based electronic apex locators. Journal of Endodontics 2003;29:497-500.

Irrigating solutions play a very important role in the removal of microorganisms, toxins, debris and smear layer from the root canals during biomechanical preparation. Barret in 1925 had once said, that "Of all the phases of anatomic study in the human system, one of the most complex is that of the pulp cavity morphology." It would thus, be unrealistic to assume that a linear streamlined instrument can reach out into the delicate and complex intricacies of the root canal to effectively debride its contents. This task falls on the wide myriad of irrigating solutions available to us today (Fig. 11.1).

Other than debris removal irrigating solutions have following functions.

1. Tissue dissolution: Proteolytic irrigants such as sodium hypochlorite can dissolve organic matter and effectively debride the canal system.

Fig. 11.1: Irrigation

2. Lubrication: Irrigants aid in the smooth passage of instruments within the canal.
3. Chelation: Certain irrigants like EDTA aid in negotiating narrow and calcified canals by substituting Ca ions and forming soluble salts.
4. Antibacterial action: Irrigants aid in the removal of pathogenic microorganisms from the root canal.
5. Certain irigants can cause a bleaching action.

Some additional newer function includes:

- Possessing certain amount of radio-opacity which aids in determining the presence of accessory/ lateral canals.

IDEAL REQUISITES FOR AN IRRIGANT INCLUDE (WALTON)

- Low toxicity
- It should be biocompatible, i.e. non-injurious to periapical tissues or intraoral tissues
- Low surface tension: As this will promote its wetting capacity
- Low neutralizability: Its action should not get nullified by canal components so as to enhance and retain its effectiveness.
- The last requirement is related to its utility such as:
  - Easy availability
  - Cost effective
  - Convenient for usage
  - Good shelf-life
  - Easy storage, etc.

Enterococcus faecalis, a gram-positive facultative anaerobic bacterium has steadily gained more importance in endodontics. This bacterium is commonly seen in re-treatment cases and in cases

where there may be contamination from saliva. It is a resistant strain that cannot be removed using routine irrigating solutions. Various irrigating solutions and their combinations have been tried in the eradication of this bacterium such as chlorhexidine gluconate, MTAD, Chlorine dioxide, Iodine potassium Iodide, calcium hydroxide with chlorhexidine, MTAD with sodium hypochlorite, etc.

IRRIGATING SOLUTIONS

- Saline
- Sodium hypochlorite
- Hydrogen peroxide
- Glyoxide
- Chlorhexidine gluconate
- Chelating agents (ethylene diamine tetra-acetic acid, RC prep)
- Decalcifiers
- MTAD
- Chlorine dioxide
- Iodine potassium iodide

Saline: Sterile saline has been recommended by some authors as an endodontic irrigant. Saline when used as an irrigant flushes debris out of the canal. Other than mechanical flushing, this irrigant does not possess any special properties of dissolution or to kill the bacteria. The major advantage is biocompatibility.

SODIUM HYPOCHLORITE (NaOCl)

Among the chemically active irrigants no other solution has been as popular as the NaOCl solution. Introduced by a physician named Dakin during World War I to treat wounds, this solution possesses the following advantages:

- Tissue dissolution
- Lubrication
- Antimicrobial and bleaching action
- It is also economical and easily available.

Drawbacks

- It causes mild to severe cellular damage and toxicity if extruded beyond the apex. The severity depends upon the concentration and volume
- It has high surface tension which decreases its dentin wetting capacity
- It is caustic and can cause inflammation of gingival tissue. Recently a case where NaOCl caused a severe burn extraorally due to its leakage from a defective rubber dam placement was reported.
- It has an unpleasant taste, odor and its vapors can irritate the eyes
- It tends to corrode equipment
- It can bleach clothes if spilt
- May cause pharyngeal edema and esophageal burns if swallowed (Seltzer).

Description

Sodium hypochlorite is a clear, straw colored, proteolytic, reducing agent having 5 percent available chlorine. It is prepared easily from household bleach like Clorox, Lenco or Purex or it can be made by dissolving sodium carbonate in chlorinated lime. It is highly alkaline with a pH of 11.0-11.5 percent.

According to most studies, a concentration of 1.5-3 percent strikes a good balance between tissue dissolution and antibacterial efficacy. The rate and effectiveness of solution can be enhanced by:

- Heating it to 60°C
- Using a larger volume
- Giving it ample time to work

The antimicrobial action of Sodium hypochlorite takes place via two modes

- The chlorine ion: when NaOCl comes in contact with organic debris/pulp tissue, hypochlorous acid is formed. The latter is able to penetrate the bacterial cell, oxidizes the sulfhydryl groups of the bacterial enzymes and disrupt the metabolism which eventually leads to their death.
- Its alkalinity: NaOCl has a high pH of 11.0-11.5 which is effective in eliminating anaerobes which need an acidic environment to thrive.

HYDROGEN PEROXIDE (H_2O_2)

It is an oxidizing agent used in a concentration of 3 percent. It is almost always used in conjunction with Sodium hypochlorite. The proponents of such combined usage claim that an interaction between the two produces:

- A transient but energetic effervescence, which can mechanically force debris out of the canal
- Another contention is that the resultant nascent oxygen production as a by product of their interaction is toxic to the anaerobes
- A side but a welcome effect is a certain amount of bleaching that occurs.

Another school of thought condemns such an interaction, which claims that the bubbles, which are produced, prevent adequate contact between the irrigant and debris. Certain reports have also discouraged this combined usage as it was seen that the effectiveness of NaOCl diminished because of this interaction. Yet another drawback is H_2O_2, if left unneutralized, can produce gas bubbles, which can cause continuous pain.

In spite of all these drawbacks Weine strongly recommends its usage because of its low toxicity. It is especially useful in canals, which have been left open for drainage as the effervescence can help dislodge food particles and debris which could have got accumulated within the canal.

Glyoxide

Another oxidizing agent, which is used, is glyoxide. It is a combination of carbamide peroxide and glycerol. Its germicidal action is greater than H_2O_2 and it is an excellent lubricant. According to Walton, there is a decreased chance of strip perforation while instrumenting curved canals.

CHLORHEXIDINE GLUCONATE (CHX)

Chlorhexidine is a broad spectrum antimicrobial agent against gram-negative and gram-positive bacteria. It has a cationic component that attaches to negatively charged cell membranes, causing cell lysis.

Chlorhexidine gluconate is recognized as being an effective oral antimicrobial agent and is routinely used in periodontal therapy and for caries prevention. Chlorhexidine, in the form of a salt, has been used since the 1950s as an oral antiseptic in mouthwash, toothpaste, and chewing gum. Chlorhexidine has been found to have broad spectrum antimicrobial action, substantivity, and a relative absence of toxicity. These properties have led to the suggestion that this solution may have some potential use as an irrigant in endodontics.

Mechanism of Action

Chlorhexidine gluconate is a cationic bisguanide that seems to act by adsorbing onto the cell wall of the microorganism and causing leakage of intracellular components. At low chlorhexidine concentrations, small molecular weight substances will leak out, especifically potassium and phosphorous, resulting in a bacteriostatic effect. At higher concentrations, chlorhexidine has a bactericidal effect due to precipitation and/or coagulation of the cytoplasm, probably caused by protein cross-linking (Fardal and Turnbull, 1986).

Its use as an endodontic irrigant is based on its broad-spectrum antimicrobial action, substantivity, and a relative absence of toxicity and long lasting antimicrobial effect, due to binding with hydroxyapatite. However, chlorhexidine gluconate is not known to possess a tissue-dissolving property Some researchers have found that CHX had significantly better antibacterial effects than calcium hydroxide on cultures. Effective combinations of CHX and calcium hydroxide are now available to counteract obligate anaerobes to make it an effective endodontic irrigant.

Chelating Agents

The commonest chelating agent used is Ethylene Diamine Tetraacetic Acid. Discovered by Nygaard Ostby in 1957, 17 percent EDTA has the properties of:

- Softening dentin effectively. Patterson reported that EDTA drastically reduced the KHN of dentin from 42 at the orifice and 70 at 1/3 distance from DEJ to a low of 7.
- Removal of smear layer when used alternatively with NaOCl.
- Demineralization of 20-30 microns (up to 50 u) of dentin when used for 5 mins.
- Antimicrobial action against certain micro-organisms.
- Relative non-toxicity causing only a moderate degree of irritation. EDTA has a near neutral pH of 7.3.

Chelating agents are either available as a liquid solution or a viscous suspension. Among the liquid solutions, same common preparations include:

- REDTA: 17 percent EDTA +8 mg cetrimide (to decrease surface tension).
- EDTAC: 15 percent EDTA +0.75 g cetavalon -von der Fehr and Nygaard Ostby in 1963.
- EDTAT: 17 percent EDTA + Tergentol (Na lauryl ether sulphate).
- EGTA: Ethylene glygol bis (amino ethyl ether) N,N,N′,N′ tetra-acetic acid (more specific Ca binding).

- Salvizol: 5 percent aminoquin aldinum diacetate + propylene glycol
- Decal: 5.3 percent oxyl acetate + 4.6 percent ammonium oxyl acetate + cetrimide
- Tublicid Plus, Largal ultra.
- CDTA: 1 percent cyclohexane-1,2 diamine tetra-acetic acid
- DTPA: Diethylenetriamine-penta-acetic acid
- Solvidont: Bis-Dequalinium Acetate (BDA)

The paste type viscous chelators are: *RC Prep:* (Discovered by Stewart) 15 percent EDTA +10 percent Urea peroxide glycol in carbowax base. This kind of a preparation allowed for:

- Increased depth of penetration
- Better debridement caused by foaming actions
- Promotion of emulsification of organic tissue. Collagen in the pulp is quite elastic and it is quite stubborn to removal. It resists repeated attempts at removal by getting stretched and then collapsing back to its original position like a rubber band. RC prep prevents this phenomenon by emulsifying the pulpal tissue and thus aids in its easy removal.
- Holds the debris in suspension by encouraging floatation of pulpal remnant which can be effectively removed by a subsequent NaOCl irrigation.
- Peroxide in the formulation causes effervescence and release of [O] on reacting with NaOCl which again aids bacterial elimination.

Decalcifiers

These are another set of irrigating solution but they have lost their popularity due to their high degree of toxicity and uncontrollable decalcifying action. They act by removing mineral salts from dentin to aid canal preparation, e.g. 30-50 percent citric acid, 30-50 percent HCl, 50 percent H_2SO_4, 40 percent Poly-acrylic acid.

MTAD (FIG. 11.2)

MTAD is a mixture of tetracycline isomer (doxycycline), an acid (citric acid), and a detergent (Tween 80). The protocol for clinical use of MTAD is 20 minutes with 1.3 percent NaOCl followed by 5 minutes of MTAD. The solubilizing effects of MTAD on pulp and dentin are somewhat similar to those of EDTA. The major difference between the actions of these solutions is a high binding affinity of the doxycycline present in MTAD for the dentin (Beltz et al J Endod, 2003). The benefit of the doxycycline in MTAD can be seen in the study by Torabinejad et al comparing it to NaOCl and EDTA in the ability to eliminate E. faecalis. MTAD is found to be as effective as 5.25 percent NaOCl and significantly more effective than EDTA. Furthermore, MTAD is still effective in killing *E. faecalis* at 200x dilution.

Fig. 11.2: MTAD

According to studies, MTAD seems to be an excellent intracanal irrigant if used according to clinical protocol. It is better than EDTA in eradication of bacteria and less cytotoxic than most irrigants. This new irrigant may help increase the success rate of root canal therapy in infected root canals.

CHLORINE DIOXIDE

Chlorine dioxide is used to eliminate contaminants from drinking water. Its disinfectant properties have been recognized since the early 1900s, and it was registered with the EPA in a liquid form for use as a disinfectant and sanitizer in 1967. Current uses include food processing, water treatment, veterinary care, surface disinfection, and dental waterline treatment. Its powerful oxidizing properties enable it to kill bacteria by disrupting the transport of nutrients across the cell wall. This strong antibacterial activity makes it a potentially useful endodontic irrigant.

Chlorine dioxide can eradicate *E. faecalis* within 30 min. At higher concentration these solutions may be able to completely eliminate *E. faecalis* from

infected tubules. Further studies need to be undertaken to establish chlorine dioxide's toxicity, effects on dentin, and minimum inhibitory concentration.

IODINE POTASSIUM IODIDE

Iodine potassium iodide is a very effective antimicrobial irrigant with low tissue toxicity. In vitro studies showed that IKI (Iodine potassium iodide 2%) penetrated deeper than 1000 micrometers of dentin in 5 mins. IKI is an effective disinfectant for infected dentin and can kill bacteria in infected dentin in 5 mins *in vitro*. IKI releases vapors with strong antimicrobial effect. The solution can be prepared mixing 2 g of iodine in 4 g of potassium iodide. This mixture is dissolved in 94 ml of distilled water. This is an effective irrigant to remove *Enterococcus fecalis* from the root canal.

Parameters for Evaluating the Efficacy of an Irrigant

- Volume
- Canal anatomy
- Working time
- Temperature of solution
- Depth of penetration
- Method of delivery of solution.

RinsEndo Irrigation System (Fig. 11.3)

RinsEndo is an effective method of disinfecting root canals. This method uses the efficiency of hydrodynamic activation on the basis of innovative Pressure-Suction Technology: 65 microliters of sodium hypochlorite solution (or other irrigating solutions) oscillating at a frequency of 1.6 hertz are aspirated each time from an attached syringe by means of a clock generator in the handpiece and transmitted to the root canal via the RinsEndo cannula.

The introduction of these fine endo cannulas into the coronal third of the prepared root canal is sufficient to enable the solution to become active. During the suction phase used solution and air are aspirated back. To ensure complete effectiveness the aspiration must be carried out by means of a surgical cannula or a saliva ejector. The pressure produced in hydrodynamic irrigation by RinsEndo, is restricted by the system and is less than that generated in conventional manual irrigation using a disposable syringe.

Fig. 11.3: RinsEndo irrigation system

Safety Irrigator (Figs 11.4A to D)

Recently Safety irrigator is introduced by Racine, WL-Vista Dental Product. This is a very simple mechanism to irrigate and suction the root canal simultaneously. Sodium hypochlorite is commonly used with this system.

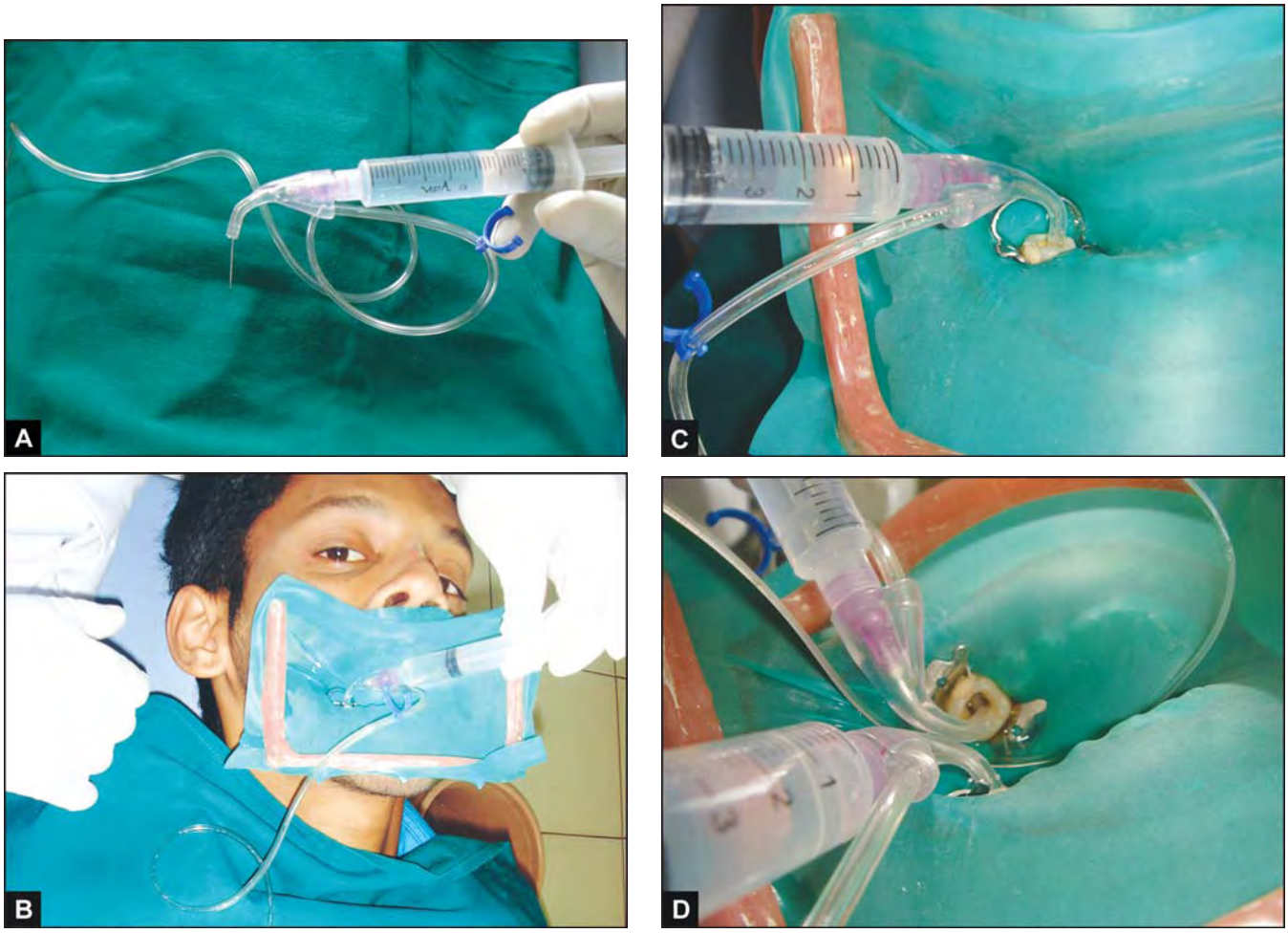
Ultrasonic Irrigating Systems

Ultrasonic irrigating systems such as "CAVIENDO" have also gained popularity because of the production of agitation, cavitations, eddy production and concurrent increase in temperature which enhance the irrigating potential. It is based on the principle of "Acoustic Streaming".

CONCLUSION

Any endodontic situation warrants a correct combination of irrigants at least till the ideal single irrigant is discovered. Choosing the right combination is essential to prevent misuse or overuse of these chemical adjuncts.

It may probably be the deciding factor between success and failure. If drops of water can make the mighty ocean, then drops of irrigants will definitely pave the way for a sound, 3-dimensional obturation.



Figs 11.4A to D: Safety irrigator

Condition	*Irrigant*
Vital pulp exposure	NaOCl +H_2O_2
Necrotic pulp	NaOCl + CHX/H_2O_2
Infected canal-exudate present	NaOCl + H_2O_2
Periapical abscess-to establish drainage	Hot water/saline Later NaOCl
Canals left open for drainage	H_2O_2 + NaOCl
Open apex/apical perforation	H_2O_2 + CHX
Curved canals	Glyoxide + NaOCl
Calcified/sclerotic canal	EDTA + NaOCl
Retreatment cases	CHX + NaOCl
Final rinse-to remove the smear layer	EDTA + NaOCl

SUGGESTED READING

1. Baumgartner JC, Mader CL. A scanning electron microscopic evaluation of four root canal irrigation regimens. J Endod 1987;13:147-57.
2. Baumgartner JC, Watts CM, Xia T. Occurrence of Candida albicans in infections of endodontic origin. J Endod 2000;26:695-98.
3. Beltz RE, Torabinejad M, Pouresmail M. Quantitative analysis of the solubilizing action of MTAD, sodium hypochlorite, and EDTA on bovine pulp and dentin. J Endod 2003;29:334-7.
4. Byström A, Claesson R, Sundqvist G. The antibacterial effect of camphorated paramonochlorophenol, camphorated phenol and calcium hydroxide in the treatment of infected root canals. Endod Dent Traumatol 1985;1:170-75.
5. Byström A, Sundqvist G. Bacteriologic evaluation of the effect of 0.5 percent sodium hypochlorite in endodontic therapy. Oral Surg Oral Med Oral Path 1983;55:307-12.
6. Byström A, Sundqvist G. Bacteriologic evaluation of the efficacy of mechanical root canal instrumentation in endodontic therapy. Scand J Dent Res 1981;89:321-28.
7. Card SJ, Sigurdsson A, Ørstavik D, Trope M. The effectiveness of increased apical enlargement in reducingintracanal bacteria. J Endod. 2002;28:779-83.

8. Evans MD, Baumgartner JC, Khemaleelakul SU, Xia T. Efficacy of calcium hydroxide: chlorhexidine paste as an intracanal medication in bovine dentin. J Endod 2003;29:338-39.
9. Ferraz CC, Gomes BP, Zaia AA, Teixeira FB, Souza-Filho FJ. Comparative study of the antimicrobial efficacy of chlorhexidine gel, chlorhexidine solution and sodium hypochlorite as endodontic irrigants.Braz Dent J 2007; 18(4):294-98.
10. Ferreira FB, Torres SA, Rosa OP, Ferreira CM, Garcia RB, Marcucci MC, Gomes BP. Antimicrobial effect of propolis and other substances against selected endodontic pathogens. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104(5):709-16.
11. Foster KH, Kulild JC, Weller RN. Effect of smear layer removal on the diffusion of calcium hydroxide through radicular dentin. J Endod 1993;19:136-40.
12. Greenstein G, Berman C, Jaffin R. Chlorhexidine. An adjunct to peridontal therapy. J Periodontol 1986;57:370-77.
13. Haapasalo HK, Sirén EK, Waltimo TM, Ørstavik D, Haapasalo MP. Inactivation of local root canal medicamentsby dentine: an in vitro study. Int Endod J 2000;33:126-31.
14. Haapasalo M, Ørstavik D. In vitro infection and disinfection of dentinal tubules. J Dent Res 1987;66:1375-79.
15. Haapasalo M, Qian W, Portenier I, Waltimo T. Effects of dentin on the antimicrobial properties of endodontic medicaments. J Endod 2007;33(8):917-25. Epub 2007;22. Review.
16. Hand RE, Smith ML, Harrison JW. Analysis of the effect of dilution on the necrotic tissue dissolution property of sodium hypochlorite. J Endod 1978;4:60-64.
17. Jeansonne MJ, White RR. A comparison of 2.0 percent chlorhexidine gluconate and 5.25 percent sodium hypochlorite as antimicrobial endodontic irrigants. J Endod 1997;20:276-78.
18. Kakehashi S, Stanley HR, Fitzgerald RJ. The effect of surgical exposures of dental pulps in germ-free and conventional laboratory rats. Oral Surg Oral Med Oral Path 1965;20:340-49.
19. Krithikadatta J, Indira R, Dorothykalyani AL. Disinfection of dentinal tubules with 2 percent chlorhexidine, 2 percent metronidazole, bioactive glass when compared with calcium hydroxide asintracanal medicaments. J Endod 2007;33(12):1473-76.
20. Kuruvilla JR, Kamath MP. Antimicrobial activity of 2.5 percent sodium hypochlorite and 0.2 percent chlorhexidine gluconate separately and combined, as endodontic irrigants. J Endod 1998;24:472-76.
21. Lin S, Zuckerman O, Weiss EI, Mazor Y, Fuss Z. Antibacterial efficacy of a new chlorhexidine slow release device to disinfect dentinal tubules. J Endod 2003;29:416-18.
22. Lin YH, Mickel AK, Chogle S. Effectiveness of selected materials against Enterococcus faecalis: part 3. The antibacterial effect of calcium hydroxide and chlorhexidine on Enterococcus faecalis. J Endod 2003;29:565-66.
23. Mehdipour O, Kleier DJ, Averbach RE. Anatomy of sodium hypochlorite accidents.Compend Contin Educ Dent 2007; 28(10):544-6, 548, 550. Review.
24. Molander A, Warfvinge J, Reit C, Kvist T. Clinical and radiographic evaluation of one- and two-visit endodontic treatment of asymptomatic necrotic teeth with apical periodontitis: a randomized clinical trial. J Endod 2007; 33(10):1145-48.
25. Mounce R. Blending irrigation, canal negotiation, and instrumentation to create ideal endodontic results.Dent Today 2007;26(8):80, 82, 84.
26. Mounce R.One man's endodontic file sponge. Armamentarium and rationale. N Y State Dent J 2007; 73(4):54-56.
27. Nair P, Sjögren U, Krey G, Kahnberg KE, Sundqvist G. Intraradicular bacteria and fungi in root-filled, asymptomatic human teeth with therapy-resistant periapical lesions: a long-term light and electron microscopic follow-up study. J Endod 1990;16:580-88.
28. Nudera WJ, Fayad MI, Johnson BR, Zhu M, Wenckus CS, Begole EA, Wu CD. Antimicrobial effect of triclosan and triclosan with Gantrez on five common endodontic pathogens. J Endod 2007;33(10):1239-42.
29. O'Hara P, Torabinejad M, Kettering JD. Antibacterial effects of various endodontic irrigants on selected anaerobic bacteria. Endod Dent Traumatol 1993;9:95-100.
30. Ormiga Galvão Barbosa F, Antônio da Cunha Ponciano Gomes J, Pimenta de Araújo MC. Influence of sodium hypochlorite on mechanical properties of K3 nickel-titanium rotary instruments. J Endod 2007;33(8):982-85.
31. Ørstavik D, Kerekes K, Molven O. Effects of extensive apical reaming and calcium hydroxide dressing on bacterial infection during treatment of apical periodontitis: a pilotstudy. Int Endod J 1991;24:1-7.
32. Ozsezer E, Inan U, Aydin U.In vivo evaluation of ProPex electronic apex locator. J Endod 2007;33(8):974-77.
33. Schoeffel GJ. The EndoVac method of endodontic irrigation: safety first.Dent Today 2007;26(10):92, 94, 96 passim
34. Schoeffel GJ.The EndoVac method of endodontic irrigation, part 2—efficacy. Dent Today 2008 Jan;27(1):82, 84,86-87.
35. Sen BH, Piskin B, Demirci T. Observation of bacteria and fungi in infected root canals and dentinal tubules by SEM. Endod Dent Traumatol 1995;11:6-9.
36. Serper A, Çalt S. The demineralising effects of EDTA at different concentrations and pH. J Endod 2002;28:501-02.
37. Siqueira JF Jr, Rôças IN, Favieri A, Lima KC. Chemo-mechanical reduction of the bacterial population in the root canal after instrumentation and irrigation with 1 percent, 2.5 percent, and 5.25 percent sodium hypochlorite. J Endod 2000;26:331-34.
38. Sjögren U, Figdor D, Spångberg L, Sundqvist G. The antimicrobial effect of calcium hydroxide as a short-term intracanal dressing. Int Endod J 1991;24:119-25.

39. Sjögren U, Sundqvist G. Bacteriologic evaluation of ultrasonic root canal instrumentation. Oral Surg Oral Med Oral Path 1987;63:366-70.
40. Sundqvist G, Figdor D, Persson S, Sjögren U. Microbiologic analysis of teeth with failed endodontic treatment and the outcome of conservative re-treatment. Oral Surg Oral Med Oral Path Oral Radiol Endod 1998;85:86-93.
41. Sundqvist G. Associations between microbial species in dental root canal infections. Oral Microbiol Immunol 1992;7:257-62.
42. Tay FR, Gutmann JL, Pashley DH. Microporous, demineralized collagen matrices in intact radicular dentin created by commonly used calcium-depleting endodontic irrigants. J Endod 2007;33(9):1086-90.
43. Vianna ME, Horz HP, Conrads G, Zaia AA, Souza-Filho FJ, Gomes BP. Effect of root canal procedures on endotoxins and endodontic pathogens. Oral Microbiol Immunol 2007;22(6):411-18.
44. Villegas JC, Yoshioka T, Kobayashi C, Suda H. Obturation of accessory canals after four different final irrigation regimens J Endod 2002;28:534-36.
45. Virtej A, MacKenzie CR, Raab WH, Pfeffer K, Barthel CR. Determination of the performance of various root canal disinfection methods after in situ carriage. J Endod 2007;33(8):926-29.
46. Waltimo TM, Siren EK, Torkko HL, Olsen I, Haapasalo MP. Fungi in therapy-resistant apical periodontitis. Int Endod J 1997;30:96-101.
47. Walton RE, Torabinejad M. Principles and Practice of Endodontics. 2nd ed. Philadelphia, Pa: WB Saunders Company; 1996;201-32.
48. Weber CD, McClanahan SB, Miller G, Diener-West M, Johnson JD. The effect of passive ultrasonic activation of 2 percent chlorhexidine or 5.25 percent sodium hypochlorite irrigant on residual antimicrobial activity in root canals J Endod 2003;29:562-64.
49. Weston CH, Ito S, Wadgaonkar B, Pashley DH. Effects of time and concentration of sodium ascorbate on reversal of NaOCl-induced reduction in bond strengths. J Endod 2007;33(7):879-81.
50. White RR, Hays GL, Janer LR. Residual antimicrobial activity after canal irrigation with chlorhexidine. J Endod 1997; 23:229-31.
51. Wu MK, Wesselink PR. Efficacy of three techniques in cleaning the apical portion of curved root canals. Oral Surg Oral Med Oral Path Oral Radiol Endod 1995;79:492-96.
52. Yeung SY, Huang CS, Chan CP, Lin CP, Lin HN, Lee PH, Jia HW, Huang SK, Jeng JH, Chang MC. Antioxidant and pro-oxidant properties of chlorhexidine and its interaction with calcium hydroxide solutions. Int Endod J 2007; 40(11):837-44.

After working length determination the next important step in root canal treatment is biomechanical preparation. In this step cleaning and shaping of canals is carried out by using different instruments which have different composition of materials (stainless steel, nickel titanium). In the beginning carbon steel was used to manufacture root canal instruments. The main disadvantages of this material were brittleness leading to breakage, and susceptibility to tarnish and corrosion. Subsequently tremendous progress in metallurgy and engineering led to the development of newer materials, like stainless steel, which are more commonly used. It has a long clinical success rate and is still being used in biomechanical instrumentation. There are certain disadvantages such as less flexibility, due to which it cannot be used in narrow and curved canals. To overcome these disadvantages, Nickel titanium was introduced. These important changes took place in early 1970s. Numerous improvements in the instrument design, shape and configuration have taken place so that the procedures can be completed with less time and fatigue to the dentists.

ENDODONTIC INSTRUMENTS

Classification

According to Grossman [based on the function]

1. *Exploring:*
   - To locate the canal orifices.
   - To determine or assist in obtaining patency of the root canal

   E.g.: Endodontic explorer and smooth broaches.
2. *Debridement:*
   - To extirpate the pulp
   - To remove cotton pellets or paper points

   E.g.: Barbed broach.
3. *Cleaning and Shaping:* These are the instruments used to clean and shape the canal (Biomechanical Preparation).
   E.g.: Reamers and files.
4. *Obturating:* For the condensation of gutta-percha and to create space laterally during root canal obturation.
   E.g.: Spreaders and pluggers, lentulospirals (engine driven, latch type of attachment and working portion is like spring, which is coated with root canal sealer).

International Standards Organization (ISO) has grouped root canal instruments according to their method of use:

Group I: Hand use only:
- Files H-type
- K-type
- Reamers and files
- Broaches

Group II: Engine driven latch type: Same design as in group I, but made to attach to handpiece. For example, Profile, Lightspeed.

Group III: Engine driven latch type: Low speed instruments with latch type attachment. For example, Gates Glidden drills and Peeso ream.

Group IV: Root canal points: For example, Gutta-percha, silver points and paper points.

According to Stock

Twisted	*Machined*
K-files	H file
K- reamer	Flex R
K-flex file	Canal master
Flexo	Heliapical
Zipperer flexicut	Flexogates
	Mc spadden engine file

Materials Used

a. In 19th century carbon steel was used for manufacturing of instruments.

Disadvantages

- Fracture tendency due to the brittleness of metal.
- Corrosion with Sodium hypochlorite irrigant and during steam sterilization.

b. In 20th century stainless steel was used by Kerr manufacturing company.

Advantages

1. It is flexible, hence less likely to fracture than carbon steel and also less susceptible to corrosion.

Disadvantage

1. When canal curvature is more than 450, instrument fractures.

c. *Nickel Titanium* (Nitinol) NiTi is most flexible

Advantages

1. Low elastic modulus and thus provides very good elastic flexibility to instrument. Hence used in curved canals.
2. Shape memory alloy—it has the ability to recover from plastic strain when unloaded and go back to original shape.

Disadvantage

1. Breakage occurs without signs of any permanent deformation.
2. Cutting efficiency is inferior to stainless steel.

d. *Titanium and aluminium alloy:* Another recent development is titanium instruments which are marketed as "Microtitane" by Micro Mega, France. They are available as reamers, K-files and H-files.

Composition

- These instruments contain 90 percent titanium
- 5 percent aluminium by weight
- These instruments have same resistance to fracture as flexible stainless steel instrument but have increased flexibility.
- They have similar cutting efficiency like stainless steel instrument
- Titanium-aluminium instrument fail to produce superior preparation results in curved canals.

Standardization

- Ingle and Levine in 1958 recommended standardization of endodontic instruments.
- Describes three features of every instrument
  a. Diameter and width
  b. Length of cutting blade
  c. Taper

1. Instrument are numbered from 10 to 100, the numbers advance.
2. By 5 units to size 60 and then by 10 units till size 100 they color coded as follows.

White	15	45	90
Yellow	20	50	100
Red	25	55	110
Blue	30	60	120
Green	35	70	130
Black	40	80	140

2. Each number shall describe the diameter of instrument in 100th of a mm at the tip.
   Eg: instrument size number 10 has a tip diameter of 0.1 mm.
3. The working blade (flutes) shall begin at the tip designated as D1, and extend till a length of 16 mm designated as D2. Taper of the instrument from D1 to D2 is in increments of 0.02 mm in width/mm of length. So, the diameter of D2 shall be 0.32 mm greater than D1
   For example: In 20 size reamer—D1 is 0.2 mm
   D2 is 0.2 + 0.32 = 0.52 mm.

OTHER SPECIFICATIONS

a. Tip angle of instrument—750 ± 150
b. Instrument sizes should increase by 0.05 mm at D1 between 10 and 60 and by 0.1 mm from 60 to 100 for increased instrument selection.
   Instruments are available in different lengths:
- 21 mm, 25 mm, 28 mm, 30 mm, 40 mm
- 21 mm length is used for molars

- 25 mm length is used for anteriors
- 28 and 30 mm length is used for cuspids
- 40 mm reamers used in preparing canals for endodontic implants.

In Jan 1976, ANSI (American National Standard Institute) granted approval of ADA Specification.

- No. 28 for endodontic files and reamer
- No. 58 for H files.

ADA Specification. No. 28 revision in March 1981 stated

- Instrument sizes No. 6, 8, 10 were added to original standardization.
- D1 and D2 changed to D0 and D16.

To negotiate narrow and calcified canals, smaller sizes of instruments are used—size 06, (pink), 08 (grey) and 10 (purple).

Length of flutes is 16 mm from tip to the extent of the flutes, i.e. D1 and D2 not specified. So recently designation has been changed to D0 and D16, where D0 signifies the tip and D16 signifies length of the flutes at 16 mm.

D0---------- D16

1 mm above D0 is D1; 2 mm above D0 is D2 and so on.

Instruments of flute length D17-D18 are also available.

Five factors considered while analyzing endodontic instrument

1. Anatomic configuration of root canal
2. Material of cutting instrument
3. Manufacturing process (grinding/twisting)
4. Design of instrument (files - reamer)
5. Irrigation used during procedure.

Manufacture of Instrument

Earlier Kerr manufacturing company designed and manufactured K type endodontic instruments.

Initially the instruments were manufactured from round tapered piano wire (carbon steel), but now they are made from stainless steel blanks.

The stainless steel wire is ground along its long axis into a four sided (square cross-section) (Fig. 12.1) or three sided (triangular cross-section) (Fig. 12.2) tapered shaft that is twisted into flutes extending 16 mm, from the top to the tip of blade.

Recently rhomboidal or diamond-shaped blanks are twisted to produce a file—K flex to increase flexibility and cutting efficiency (Fig. 12.3).

Fig. 12.1: Square cross-section

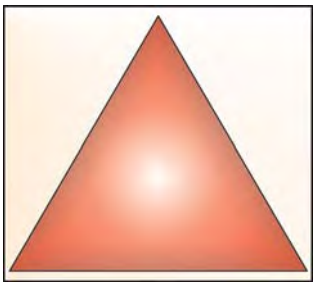


Fig. 12.2: Triangular cross-section

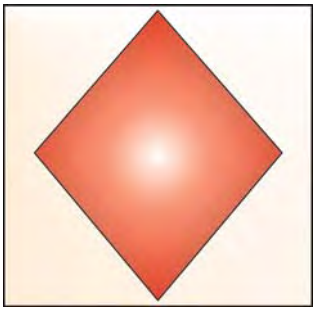


Fig. 12.3: Rhomboidal cross-section

When twisted,
Square blank produces rigid instrument, the triangular shape produces flexibility,and the rhomboid shape produces more flexibility.

When machined, the depth of cut used to produce the flutes dictates the flexibility and strength of the instrument. They tend to be more susceptible to fracture.

The number of flutes twisted into each blade determines whether instrument is a file or reamer.

- Files—tighter flutes
- Reamers—looser flutes

Most commonly used instruments for biomechanical preparation are:

1. *Broaches and Rasps:* These are the oldest endodontic instrument.
   - Used for removal of pulp tissue
   - Used for removal of cotton or paper points from root canal.

   Broach : Coronally angulated barbs
   Rasp : Perpendicular to long axis of meta
   Both are not used beyond middle 3rd of root canal.
2. Reamers
3. Files
   a. H files
   b. K files

Hedstroem Files (H Files) (Fig. 12.4)

1. These instruments are manufactured from tapered stainless steel wire of circular cross-section and machined to produce spiral flutes resembling cones or screw.
2. H files were introduced to improve the cutting efficiency.
3. It is better to use H file initially followed by K file.

Advantages are:

1. Improved cutting efficiency
2. Debris will be pushed coronally

Unifiles

Machined from round stainless steel wire by cutting two superficial grooves to produce flutes in a double-helix design.

The cutting edges may be generated by twisting the metal shaft along its long axis or by machining it.

K- File Features

These are manufactured by cutting through a blank of square or rhomboidal shape.

The number of flutes are more, i.e. the instrument have between ¼ and ½ spiral flute per mm length.

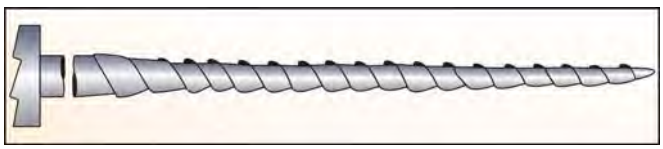


Fig. 12.4: H file

The blade angle makes them best suited for cutting dentine using a push pull filing motion with lateral pressure along the walls.

The function of file is to smoothen the canal.

Disadvantages

1. Debris extrusion and reduced cutting efficiency.

K Reamer (Fig. 12.5): First designed as early as 1904 by the Kerr Manufacturing Company.

Features

- The number of flutes are less as compared to a file
- Manufactured by twisting the triangular blank
- The cross-section is triangular in shape which makes reamer more flexible than files.
- Flutes are placed farther apart and hence, more space between flutes allowing better transport of dentin debris
- These instruments have less than one-tenth to one quarter of a spiral per mm of length. Cuts more efficiently using a rotary motion, hence reaming action is used.
- They are more efficient in cutting tooth structure (dentine). Reamer should be used by reaming motion, i.e. ¼th or ½ anticlockwise rotation followed by clockwise rotation to prevent breakage of the instrument.

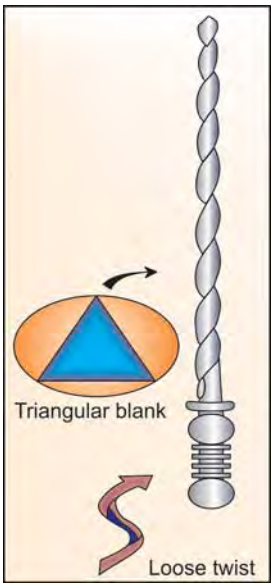


Fig. 12.5: K reamer

Files	*Reamers*
Square cross-section	Triangular cross-section
Cross-sectional area greater	Lesser
Tighter flutes (1.93-0.88 mm)	Loose spirals (0.8-0.28 mm)
Resists fracture better	Fracture easily
Less flexible	More flexible (less work hardening)
Lower cutting efficiency, work best in filing motion	Better cutting efficiency (2.5 times more efficient), best in reaming motion. But lose sharpness easily.
Square shaft requires 1/4th turn to complete a cutting circle of the root canal wall	Triangular shaft requires 1/3rd rotation to complete a cutting circle of the root canal wall
Helical angle is large	Small
Cutting mode is clockwise turn and pull, or pull only	Clockwise turn only
Ovoid preparation	Rounded/key hole

K Style Modification—K Flex File (Fig. 12.6)

1. It was introduced in 1982.
2. This instrument is twisted from a tapered blank with a rhomboidal cross-section.
3. Alternating high and low flutes that increase flexibility and cutting efficiency of instrument and also facilitate removal of debris.
4. Acute angle (< 90) improves cutting efficiency.
5. Obtuse angle (> 90) does not contact root canal.

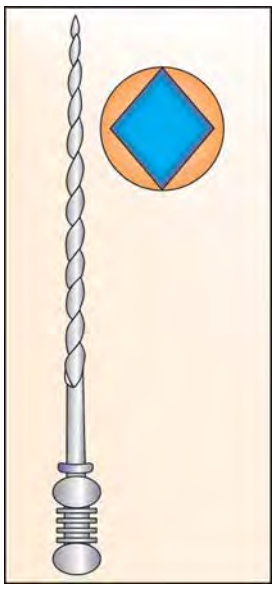


Fig. 12.6: K flex file

Advantages

- Increased debris removal
- Used in curved and narrow canals.

Flex O Files

- It is very similar to K file but is made from softer, more flexible steel.
- It does not fracture easily and is very flexible.
- Tip is modified to non-cutting.

Golden Medium

1. These are range of intermediate files, initially described by Weine.
2. Provide half sizes between traditional instruments for narrow canals.
3. Instrument should be intermediate to standard size. Sizes from 12-37 (12, 17, 22, 27, 32, 37) manufactured by Maillefer.
4. Weine suggested trimming 1 mm from the tip of the file and rounding off sharp edges on a diamond nail file. In this way, file sizes 10, 15, 20, 25, may be converted to 12, 17, 22, 27.

Flex R File

Introduced by James Roane:

- Designed to be used in balanced force technique.
- Machined from blank of triangular cross-section
- Non-cutting tip.

ADVANCES IN HAND INSTRUMENTS

Nickel-Titanium Files

In 1988 the properties of a file manufactured from nickel-titanium alloy was reported.

This file demonstrated greater elastic flexibility in bending and showed greater resistance to the torsional fracture than stainless steel. Ni-Ti files have a non-cutting tip. Precurving is not necessary as it is flexible to follow the canal curvature due to superelasticity.

1. *Greater Taper Hand Files:*
   - Made of Nickel Titanium. Each instrument is designed to be active in counter clockwise direction and has a D0 diameter 0.2 [D0 -0.2]
   - Greater taper files have increasing tapers of 0.06, 0.08, 0.10, 0.12 /mm
   - The length of the blades varies from file to file depending on the taper.

2. *Mac Files and Double MAC Files:* The MAC files are the newer instruments manufactured from Ni-Ti alloys. It has a working surface demonstrating dissimilar helical angles with blades that spiral round the shaft at different rates. According to manufacturer this allows the instruments to stay relatively loose within the canal and balances the forces of the file against the canal wall during rotation to prevent canal transportation.
   Double MAC files have a series of increasing tapers from 0.03 to 0.05 mm/mm length.
3. *Canal Master-U (Fig. 12.7):* Canal master-U (CMU) hand instrument was developed in the late 1980s. It has 0.1 mm non-cutting pilot tip in order to follow the canal curvature without gouging or ledging. Cutting blade is 1 mm in length and Flutes are machined from circular blanks. It has non-cutting parallel shaft with diameter smaller than that of cutting blade.

Advantages

- This instrument is designed to improve debris removal and to minimize apical extrusion.
- Creates a well centered canal preparation without ledging and transportation.

Drawbacks

- Inconsistencies in the taper and length of the cutting head and generally predisposed to wear and breakage.
- When these instruments separate, it tends to be at a point close behind the cutting head and all fractures are sudden.

Canal master U instruments are now being manufactured using Ni-Ti thus, leading to the increased flexibility and are known to produce better canal shaping as compared to other instruments..

4. *Flexogate (Handygate) (Fig. 12.8):* It is a logical development of the Gates-Glidden drill. It is similar in design and use to the CMU hand instrument. Flexo gates are used in enlarging the apical region of the canal. Flexo gates demonstrate a non-cutting guiding tip. Debris evacuation zone helps to maintain root canal configuration during instrumentation.

Advantages

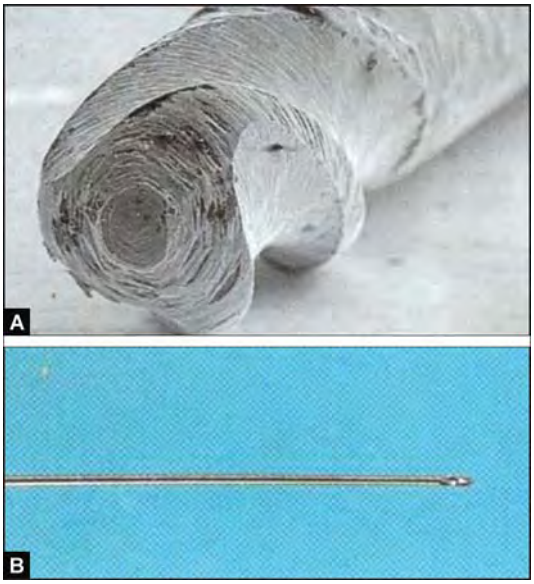
- Flexogates is less likely to cause apical transportation.
- It has a breakage point 16 mm from the tip, which ensures its retrieval in the event of separation.
- Considerable flexibility in curved canals.

Drawbacks

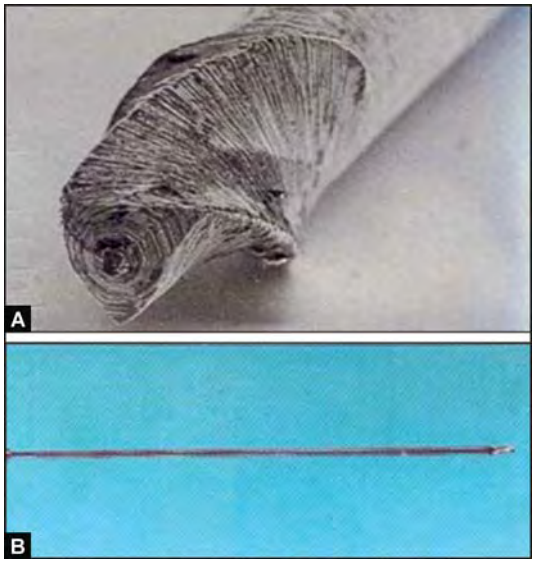
- Flexogate can fracture more readily or easily during torsion than the canal master-'U'.

5. *EZ-FILE (Safe Sided System) / (Flute Modification):*

- A series of non-circular instruments that have a pat ended, non-interrupted flat sided architecture.



Figs 12.7A and B: Canal master U
(*Courtesy:* Christopher J Stock 2nd edition)



Figs 12.8A and B: Flexogates
(*Courtesy:* Christopher J Stock 2nd edition)

- This allows negotiation of any type of canal to the apex while applying less force.

Method of Use

- These are usually used in watch winding motion.
- Never used in push or pull strokes
- Clockwise direction engages the dentin
- Anticlockwise direction removes the dentin.

Available in Sizes

- 8 and 10—0.02 taper to negotiate apex
- 15 to 40—0.02 taper non circular
- 30 (Ni-Ti)—0.04 taper orange color
- 25 (Ni-Ti)—0.08 taper brown color

ISO GROUP II AND III INSTRUMENTS (ROTARY)

Engine driven instruments can be used in different types of handpieces.

Handpieces

1. *Contra-angle handpiece:* Contra-angle handpieces are available in three types. They are:
   a. Full rotary handpiece (either latch/friction grip).
   b. Reciprocating/quarter turn handpiece.
   c. Vertical stroke hand piece
   A random motion may also be imparted by the handpiece.

a. Rotary Handpiece

Specially designed handpieces providing a mechanical action to a root canal cutting instrument have been available for 30 years. They are all designed to reduce the time spent in canal preparation.

Applications

- Full rotary handpiece is used in straight-line drilling or side cutting.
- It is used to get coronal access to the canal orifice by using round or tapered burs or diamond points.
- It is used to funnel out the orifices for easier access to clean and shape canals with slow turning Ni-Ti reamer type instruments.
- It is used to prepare post channel for final restorations.

Drawbacks

- These handpieces are used for straight line drilling, as instruments do not readily bend and they should be limited to the straight canals only.
- They are often misdirected or forced beyond the limits and may cause perforations.

Reduction Gear Handpiece

The full rotary handpieces have many drawbacks due to their high speed. Hence, reduction gear handpiece with low speed has been introduced.

- These motors are specially designed to power the new Ni-Ti instruments in canal preparation.
- The speeds vary from 300 to 2,000 rpm. 300 rpm is suggested for Ni-Ti ProFiles and 2000 rpm is suggested for Light Speed instruments. That is, the speed and torque can be set for a certain size instrument and handpiece will "stall" and reverse if the torque limit is exceeded.

Examples of reduction gear handpiece:

- Medidenta/Micro mega MM 324 reduction gear handpiece
- Quantce ETM (electric torque control motor)
- Moyco/union broach sprint EDM (electronic digital motor handpiece)
- Anthogyr (Dentsply) (Fig. 12.9)
- Aseptico ITR Motor
- The Nouvag TCM Endo motor
- New Endo-pro electric
- New pro Torque motor
- Ni-Ti matic (Fig. 12.10)

TRI AUTO ZX (FIG. 12.11)

A new system in rotary handpiece is TRI AUTO ZX (J. MORITA)

- It is a cordless, battery powered, endodontic slow speed handpiece with built-in apex locater

Fig. 12.9: Anthogyr

Fig. 12.10: Ni-Ti Matic

Fig. 12.11: Triauto Zx

- It uses rotary Ni-Ti instrument held by a push button chuck.

Advantages

- The handpiece automatically starts when the file enters the canal and stops when the file is removed.
- If more pressure is applied, the handpiece automatically stops and reverses the direction of rotation.
- It also automatically stops and reverses rotation when the file tip reaches the apical terminus as determined by the apex locater (built-in).

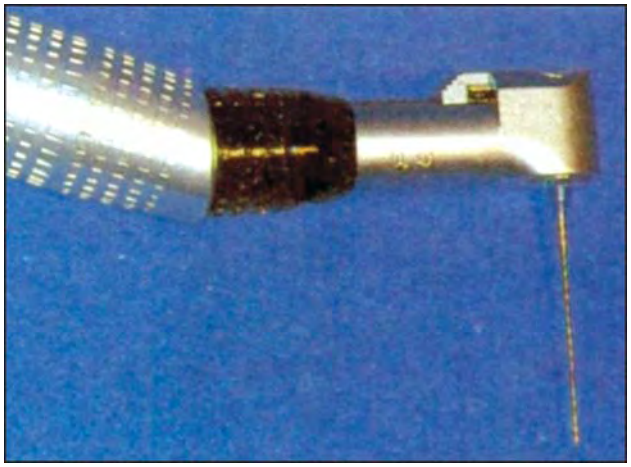


Fig. 12.12: Giromatic handpiece

Applications of Reduction Gear Handpiece

- Used in slow speed
- Gates Glidden drills, Peaso reamers, rotary H type, K-type instruments can be used.
- Used to flare and prepare cervical and middle portions of the canal with orifice opener.
- Ni-Ti rotary and finishing files can be used.

b. Reciprocating Handpiece

Reciprocating handpieces are available as follows:

i. Giromatic Handpiece (Fig. 12.12)

- It is the first machined handpiece. Nowadays it is not being used by the endodontists.
- In this device the quarter turn motion is delivered 3,000 times per minute.
- It accepts only latch type instruments.
- It accepts barbed-broach type files (Rispi) and three sided files (Heli files).
- The continuous rotation of the drives in the hand piece is transformed into an alternating quarter-turn movement of the file.

Drawbacks

- It leads to uneven canal preparations
- It was not able to accept all the instruments
- Lack of expertise.

ii. M4 Safety Handpiece (Fig. 12.13)

- It is marketed by Sybron-Kerr
- It has a 30-degree reciprocating motion

Fig. 12.13: M4 Safety handpiece

- It has a simplified chuck mechanism activated by the thumb pressure to accommodate a plastic-handled root canal instrument.
- It has a 4:1 gear ratio, which even at full speed demonstrates minimal torquing.
- The Kerr Company recommended that their safety Hedstrom instrument be used with M4.

Method of Use

The handpiece lets the instrument glide along the walls of the canal by mimicking commonly used hand movements.

iii. Endo-Gripper Handpiece (Fig. 12.14)

- It is marketed by Moyco/Union Broach.
- It is a similar handpiece with a 10:1 gear ratio with 450 turning motion
- Endo-Gripper also uses regular hand instruments rather than the contra-angle instruments.
- Union broach recommends their flex-R files.

iv. Canal Finder System (Fig. 12.15)

- The canal finder system consists of a contra angle handpiece powered by a micro motor that runs at speed above 3000 rpm.
- It produces a reciprocal screwing action
- It enables the file to cleave rather than abrade the canal wall
- It advances along the path of least resistance, maintaining the original pathway.
- Specially designed files rotate the file slightly when resistance from the canal is met.
- This system is of benefit in initial preparation of extremely curved and narrow canals.
- It has a tendency to straighten canals with over instrumentation and widening of the apical foramen.

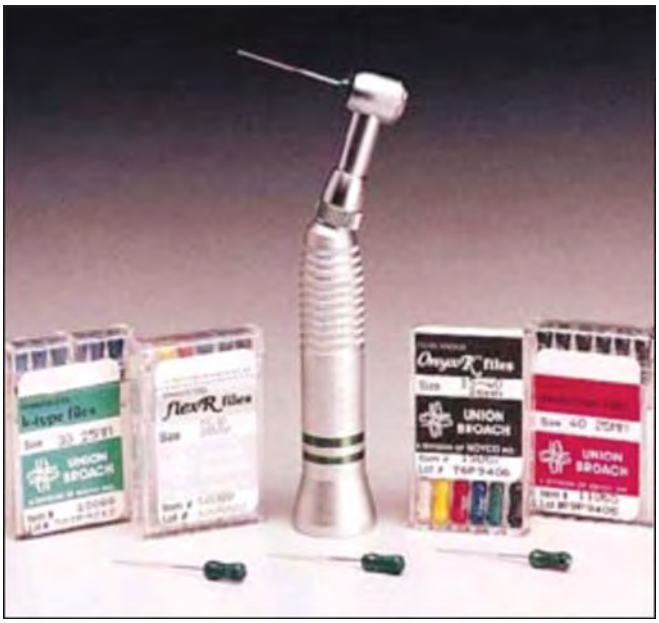


Fig. 12.14: Endo-Gripper handpiece

Fig. 12.15: Canal Finder System

- Developed in France, the Canal Finder system uses the A file, a variation of H-file.

c. Vertical Stroke Handpiece

- These are the special handpieces that imparts a vertical stroke
- With the added reciprocating quarter turn, it cuts in when the instrument is stressed.
- Levy introduced a handpiece that is driven either by air or electrically and delivers vertical strokes ranging from 0.3 to 1.0 mm.
- The more freely the instrument moves in the canal, the longer the stroke.

Mode of Action

- The handpiece with quarter turn reciprocating motion kicks in along with the vertical stroke, when

the canal instrument is under tension in a tight canal.
- If the instrument is too tight in the canal, the operator should use a smaller file.

Racer

The Racer contra angle handpiece uses a standard file and oscillates the file in the root canal. The instrument length can be adjusted to the working length using this contra angle handpiece.

Disadvantages

- A major disadvantage of this instrument is that debris may be forced ahead of the instrument, with resulting clogging of the canal or pushing of debris into periapical tissue.
- When engine driven instruments are used till the apical foramen, access must be made first by hand instrumentation.
- Ring found that root canals could not be enlarged with the Racer instrument in 13 percent of cases.

D. Random

Excalibur

- Runs at a speed of 20,000-25,000 rpm. Can be attached to the air motor line in the dental unit. The water flow in the air motor line passes it through the handpiece and irrigates root canal.
- This uses specially modified K type files.
- This handpiece works rendering random vibratory movement laterally on endodontic files and is devoid of vertical movements.
- The oscillation frequency is about 1000-2000/ second and amplitude of movement is 1.5 -2.0 mm.

2. Ultrasonic Handpiece

Although Richman must be credited with the first use (1957) of ultrasonics in endodontics, Howard Martin in 1976 was the first one to develop a device for preparation and cleaning of root canals and named this technique as "Endosonics". Ultrasonic devices are driven by magnetostriction or piezoelectricity, resulting in oscillation (25-40 kHz) of the inserted file which initiates acoustic micro streaming in the irrigation fluid. Instruments used in the handpiece that move near or faster than the speed of sound, range from standard K-type files to special broach- like instruments.

Mode of Action

The main debriding action of ultrasonics was initially thought to be by cavitations, a process by which bubbles formed from the action of the file, become unstable, collapse and cause a vacuum like implosion. Some researchers believe that a different physical phenomenon, "Acoustic Streaming," is responsible for the debridement. A combined shock, shear and vacuum results.

These instruments all deliver an irrigant which is usually sodium hypochlorite into canal space while cleaning and shaping are carried out by a vibrating K-file.

Transient cavitation does not play a role in canal cleaning with Cavi Endo unit; however, acoustic streaming does appear to be main mechanism involved. Acoustic streaming depends on free displacement amplitude of file. The vibrating file is dampened in its action by the restraining walls of canal.

Stamos et al compared cleanliness following ultrasonic debridement with sodium hypochlorite or tap water. Using water alone, the Enac system was more effective, but when sodium hypochlorite was used, the CaviEndo unit (which has a built-in tank) was superior. They also reported ultrasonic preparation to be significantly faster than hand instrumentation.

Different ultrasonic devices available are:
- Cavitron endodontic system (Densply)
- ENAC (Osado electric Co)
- Piezon master 400 (Eletro medical systems)

CAVITRON ENDODONTIC SYSTEM (FIG. 12.16)

- Developed and marketed by Cunningham in 1976.
- It utilizes K, and K-flex and diamond impregnated files.
- Modified Cavitron has magnetostrictive power source
- Its vibrations range around 25 kHz.
- It generates heat and hence requires a cooling device. It has special tube connections from the reservoir (for the supply of the irrigant) and from the supply point of compressed air

Fig. 12.16: Cavitron Endo Unit

Cavitron Endo system had disadvantages that it was slow, blocked and ledged canals, and fractured files in severely curved canals.

EMS PIEZON MASTER 400 (FIG. 12.17)

Advantages

- Smaller files generated acoustic streaming and hence much cleaner canals.
- The K-flex is more efficient than the regular K-style files.

Drawbacks

Greatest displacement amplitude occurs at the unconstricted tip and greatest resistance occurs when instrument is negotiating the apical third of a curved canal.

- Lack of freedom for the tip to move freely to either cut or cause acoustic steaming to cleanse
- Irrigant could not advance to the apex until the file could freely vibrate.
- K-files had to be precurved when used in the curved canals.
- Ultrasonics alone actually increased the viable counts of bacteria in simulated canals and it may be due to the lack of cavitation and dispersal effects of the bacteria by the acoustic streaming.

3. Sonic Handpieces (Fig. 12.18)

The principal sonic endodontic handpiece available today is the MICRO MEGA 1500 SONIC AIR ENDO SYSTEM (OR 1400). It is marketed by MEDIDENTA / MICRO MEGA. Like the air rotor handpiece, it attachés to the regular airline at a pressure of 0.4Mpa. The air pressure may be varied with an adjustable ring on the handpiece to an oscillatory range of 1,500 to 3,000 cycles /second. Tap water irrigant or coolant is delivered into the preparation from the handpiece.

Mode of Action

The sonically powered files in this handpiece oscillate in a large elliptical motion at the tip. When loaded into the canal oscillation motion changes into a longitudinal motion, up and down, a particularly efficient form of vibration for the preparation of root canals.

Fig. 12.17: EMS Piezon Master 400

Fig. 12.18: Micro Mega 1500

Fig. 12.19: Micro Mega Sonic files
(*Courtesy:* Endodontics by Ingle)

The strength of Micro Mega sonic handpiece lies in the special canal instruments used and ability to control air pressure and hence the oscillatory pattern.

The files used in Micro Mega 1500 are (Fig. 12.19):

a. Rispi sonic files (Dr Retano Spina in Italy)
b. Shaper sonic files (Dr JM Laurichesse in France)
c. Trio sonic files

Advantages

Ripsi sonic and Shaper sonic files were significantly more efficient faster in preparation time and caused the least amount of straightening of the canal.

Drawbacks: Debris extrusion was more.

NICKEL TITANIUM INSTRUMENTS

A new generation of endodontic instruments, made from a remarkable alloy, nickel titanium, has added a striking new dimension to the practice of endodontics.

The super elasticity and shape memory of nickel titanium, properties that allow it to return to its shape following significant deformation, differentiate it from other metals such as stainless steel that sustain permanent deformation and retain the shape change. These properties make Ni-Ti endodontic files more flexible and better able to conform to the canal curvature, resist fracture and wear less than stainless steel files.

In the early 1960s, the super elastic property of nickel-titanium alloy, also known as Nitinol, was discovered by Buehler and Wang at the US Naval Ordnance Laboratory. The name Nitinol was derived from the elements that make up the alloy, nickel and titanium, and "NOL" for the Naval Ordnance Laboratory. The same alloy had been manufactured in Shanghai, China since 1979 as "Nitialloy"-containing 56 percent of Nickel and 44 percent Titanium. The first investigation of nickel titanium in endodontics was reported in 1988 by Walia, Brantley, and Gerstein who found that 60-Nitinol is better for fabrication of tough corrosion-resistant hand and rotary cutting instruments.

Endodontic files (No.15) fabricated from Ni-Ti orthodontic alloys shown 2-3 times elastic flexibility in bending and torsion, as well as superior resistance to torsional fractures, compared to stainless steel No: 15 files. (Walia H, Brantley WA, JOE 1988; 14:346.)

In 1992 May, Serene introduced new files to students in the College of Dental Medicine at Medical University of South Carolina. Later these files become available to the profession generally.

- It shows shape memory effect and super elasticity - Transformation of stress induced martensite (during work) to austenite phase (parent structure).
- Deformations involving as much as a 10 percent strains can be completely recovered.
- Super elasticity occurs over a limited temperature. Minimal residual deformation occurs at approximately room temperature.
- A composition consisting of 50 percent nickel and 50 percent atomic titanium seems ideal both for instrumentations and manufacture.

Manufacture

Today nickel-titanium instruments are ground into different designs and made in different sizes and shapes. For example:

- K-style hedstroem files
- X-double flutes files
- S-double flutes files
- U-files
- U and drill designs
- Rotary files
- Canal master, etc.

Advantages

- Nickel titanium files have greater flexibility than conventional stainless steel files.
- They are more wear resistant, biocompatible and have better anticorrosive properties.
- Recently high torque rotary motors (automatic reversal) have been introduced that have decreased rotary instrument breakage.
- Incorporation of new designs such as radial lands can be achieved with latest CNC technology. Radial land allows Ni-Ti files to be used in a 3600 motion as reamers.
- Few systems also allow the conversion of hand to rotary and vice versa using adapters or conversion handles.
- Electro polishing has also reduced instrument breakage and increased cutting efficiency.

From these advances, a change may take place from high torque instruments such as stainless steel to low torque instruments such as Ni-Ti instruments which are more efficient and safer when used passively.

Drawbacks: Lower resistance to fracture. Separation usually occurs at the point of maximum curvature of the shaft.

The following principles should be followed while using nickel titanium instruments to improve the efficiency of biomechanical preparation.

1. Measurement of each file before inserting into the canal.
2. Inspection of each instrument before inserting into a canal, preferably under magnification.
3. Excessive force should not be applied to the file.
4. In teeth with multiple canals these instruments first should be used in relatively straight canals followed by curved canals, Files should not be over used, especially in curved canals.
5. Bayonet shaped or S-shaped canals should always be instrumented following coronal flaring. Avoid cutting with entire length of the file blade.
6. Sudden changes in the direction of instrument must be avoided.
7. Proper access preparation is very important to avoid procedural errors.
8. Advancing or pushing instrument too much may cause increased stress on the metal.

Instrument Design (Fig. 12.20)

Helical Angle

It is very important for cutting efficiency. If the helical angle is uniform, cutting efficiency is less. The instruments having variable helical angle have better cutting efficiency.

Rake Angle (Fig. 12.21)

Rake angle is the angle formed by the leading edge and the long axis of the file. If the angle formed by the leading edge and the surface to be cut (its tangent) is obtuse, the rake angle is said to be positive or cutting. If the angle formed by the leading edge and the surface

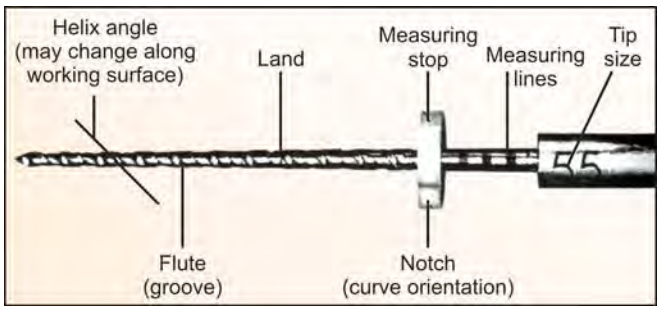
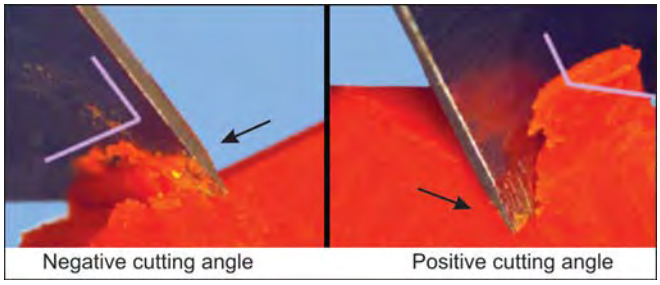


Fig. 12.20: General Instrument design of NITI Instruments (*Courtesy:* Cohen pathways of pulp—9th edition)



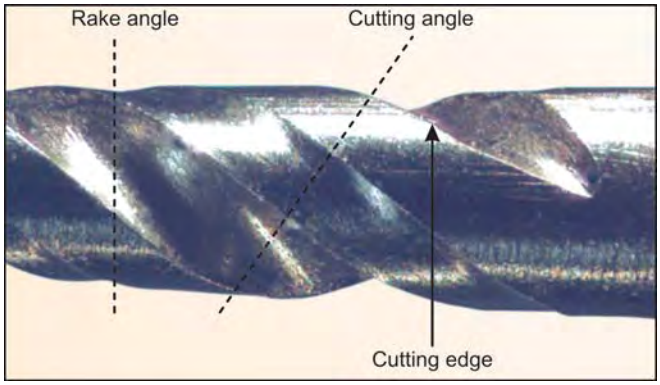


Fig. 12.21: Negative and positive cutting angles

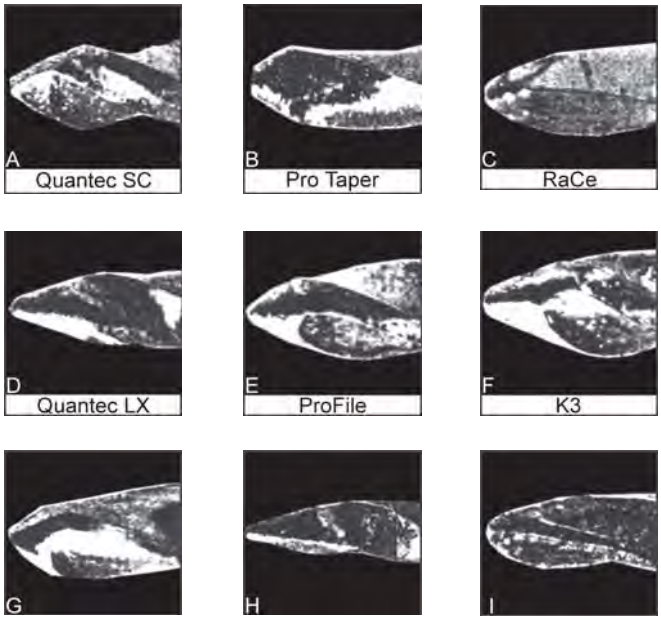


Fig. 12.22: Tip designs
(*Courtesy:* Cohen pathways of pulp—9th edition)

to be cut is acute, the rake angle is said to be negative or scraping. Slightly positive rake angle increases the cutting efficiency and high increase in positive rake angle values may result in dragging and gouging of the surface to be cut. The rake angle is balanced in order to increase the cutting efficiency.

The cutting angle or the effective rake angle, is a better indication of the cutting ability of a file and is obtained by measuring the angle formed by the cutting (leading) edge and the radius when the file is sectioned perpendicular to the cutting edge. In some instances, as with some Quantec files, a file may have a blade with a negative and a positive cutting angle. If the flutes of the file are symmetrical, the rake angle and cutting angle will be essentially the same.

Tip Design (Fig. 12.22)

Tip design may be cutting or non-cutting. Instruments with specific tip design are selected depending on morphology of root canal system.

Instrument Taper

Manual stainless steel K files (ISO) have 0.02 taper while Ni Ti rotary instruments have a taper ranging from 0.02 to 0.12. The issue of increased tapers is a controversy as some researchers consider that unnecessary tooth structure removal occur with increased tapers. The instrument taper to be selected should be based upon the morphology of root canal system.

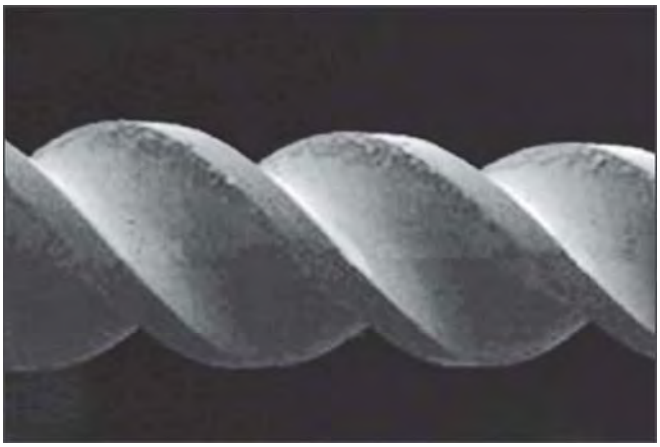


Fig. 12.23: Pitch of a file

Radial Land

Radial land enhances the canal centering ability of the instrument. Radial land and non-cutting tip together reduce the chances of canal transportation.

Pitch (Fig. 12.23)

The pitch of the file is the distance between a point on the leading edge and the corresponding point on the adjacent leading edge, or it may be the distance between points within which the pattern is not repeated. The smaller the pitch or the shorter the distance between corresponding points, the more spirals the file will have and the greater the helix angle will be. Most files have a variable pitch, one that changes along the working surface, because the diameter increases from the file tip towards the handle. The flutes become proportionately deeper resulting in the core taper that is different from the external taper.

Core of a File (Fig. 12.24)

The core is the cylindrical center part of the file having its circumference outlined and bordered by the depth of the flutes. The flexibility and resistance to torsion is partially determined by the core diameter. The importance of the ratio of core diameter to total diameter is often overlooked in predicting a file's susceptibility to failure and can be different for each file size of the same series.

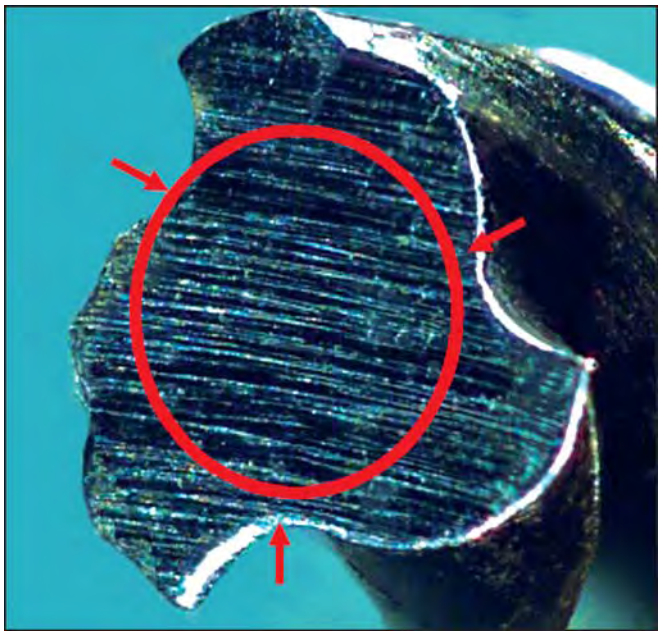
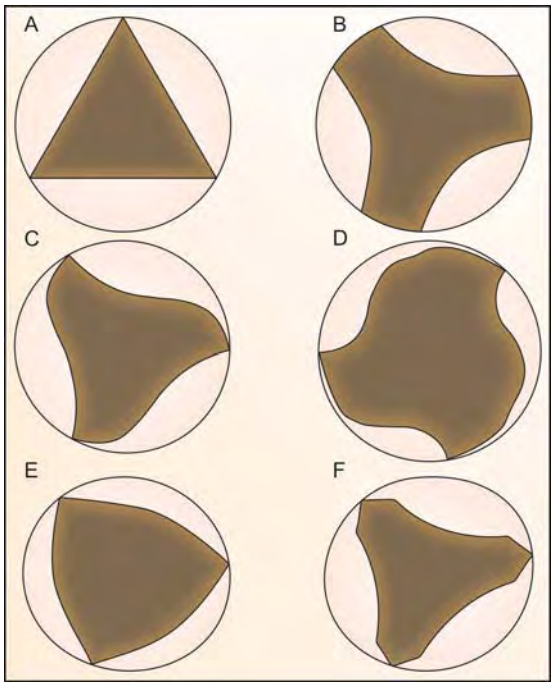


Fig. 12.24: Core of the file



Figs 12.25A to F: Cross-section designs of various rotary instruments (A) Race, K design; (B) Profile GT, light speed; (C) Hero-642; (D) K3; (E) Protaper, flexmaster; (F) Protaper (F3)

ROTARY INSTRUMENTS (FIGS 12.25A TO F)

The introduction of nickel titanium (NiTi) rotary instrumentation has been one of the most significant changes in endodontics in the past decade, allowing easier, faster and better root canal shaping. This improvement is because of a combination of the unique mechanical properties of the alloy, innovative file design and a crown-down procedure. However, a concern expressed by dentists using rotary instruments is a higher incidence of fracture.

Different systems are:

- Light speed
- Martin's Orifice opener
- ProFiles systems
- Prosystem GT instruments
- Rapid Body shapers
- Pow-r nickel-titanium system
- Quantec system
- Hero-642
- Race
- Flex master
- ProTaper system
- K3 system
- Mtwo
- Endo Sequence
- V-taper
- Liberator

LIGHT SPEED ENDODONTIC INSTRUMENTS

The light speed rotary instrumentation system is so named because of the light touch needed as the speed of instrumentation is increase. It involves the use of specially engineered Ni-Ti Gates Glidden drill-like reamers that allow for enhanced tactile control and apical preparations larger than those created via conventional techniques and other Ni-Ti rotary systems.

Design (Fig. 12.26)

It is more flexible with slender and parallel shaft. The head has short cutting blades that only binds at its tip, with three flat radial lands which keeps the instrument from screwing into the canal. A non-cutting pilot tip and a small diameter non-cutting flexible shaft smaller than the blade, eliminate contact with the canal wall. Laser etched length control rings on

Fig. 12.26: Light speed endodontic instrument

the shaft eliminate the need for silicone stops. The light speed instrument has a cross-sectional "U" blade design in which flat radial lands with neutral rake angles enhance planing of the canal walls and centering of the instrument within the canal. The helical blade angle and narrow shaft diameter facilitate debris removal coronally.

Available as:
The set of instruments consists of ISO-sized rotary files from size 20 through 140 including nine half sizes ranging from 22.5 through 65. The half size helps reduce stress on both the instruments and root during preparation and decrease the amount of cutting that each instrument must accomplish.

Mode of Action

- In most clinical cases about 8 to 14 instruments are needed.
- They are used in continuous 3,600 clockwise rotation with very light apical pressure in a slow-speed handpiece.
- The recommended rpm is between 750 and 2000 rpm with preference towards 1,300-2,000 range.

Advantages

- Better preparation of the apical portion of the canal to a size larger than what can normally be produced using tapered instruments.
- The light speed head with its short cutting blades only binds at the tip, thus increasing the accuracy of the tactile feedback.
- Results in rounded and centered apical preparations.

Canal Preparation

Following proper coronal access, preflaring with Gates Glidden drills or any other method is recommended. Then working length is established with at least No:15 stainless steel K-file. Prior to using the light speed in the handpiece, the clinician should first select and hand fit a light speed instrument that binds short of the working length (FLSB). Once fitted, that Light Speed instrument is inserted in the gear-reduction, slow-speed handpiece. The Light Speed must enter and exit the canal at the proper rpm, preferably 1,300 to 2,000 rpm for smoother and faster instrumentation. As with other systems, the rpm must be kept constant to avoid abrupt changes that may result in loss of tactile feedback and instrument breakage.

There are two recommended motions with LightSpeed: (1) if no resistance is felt, the instrument is gently advanced to the desired length and withdrawn, or (2) if resistance is felt, a very light apical pecking motion (advance and withdraw motion) should be used until working length is attained. In either case, the instrument should never stay in one place as this increases transportation and enhances separation. This gentle pecking motion prevents blade locking, removes debris coronally, and aids in keeping the blades clean.

Increasingly larger LightSpeed instruments are used to the working length, never skipping sizes, including the half-sizes. Irrigation should occur at least once after every three instruments. Once the apical stop has been established, the LightSpeed should never be forced beyond this point. If forced, buckling along the shaft may occur, potentially leading to fatigue and instrument separation

The MAR, or Master Apical Rotary (LightSpeed size to reach the working length, yet large enough to clean the apical part of the canal), becomes the subsequent instrument that first binds 3 to 4 mm short of the working length (12 pecks rule). This instrument will require 12 to 16 pecks (i.e. 4 pecks per millimeter advancement) to reach the working length. This MAR, typically larger than the size achieved with most other methods, has been shown to clean the sides of the canal while remaining centered and creating a round preparation.

The apical 4 mm of the canal is shaped used sequentially larger instruments in step-back sequence with 1 mm intervals. The remainder of the step-back is done by feel. Finally, the last instrument taken to full working length is used for recapitulation. The taper of a canal prepared with LightSpeed is approximately 0.025 mm/mm to preserve tooth structure. To prevent instrument separation from torsional overload or from buckling along the shaft (cyclic or bending fatigue), LightSpeed instruments must always be used with light apical pressure -never forced. If the blade breaks off, it frequently can be bypassed.

ORIFICE OPENER

It was developed by Martin. Available in sizes from 25 through 70(ISO). Shaft design is square with straight and vertical blades. It is more flexible than Gates Glidden and mostly preferred in straight portions of the canal preparations. It is used to flare and prepare the cervical and middle portions of the body of the canal and preferably used with reduction gear handpiece.

Available as:

- The length of orifice opener is 19 mm with cutting length of approximately 9 mm. ISO tip sizes of 30,40 and 50 are built into these files with tapers of 0.06 and 0.07.

Advantages

- Less chances of breakage
- Easy to manipulate in areas with difficult access.

PROFILE SYSTEMS

The introduction of engine-driven instruments in tapers greater than the standard 2 percent taper in 1992 by Dr W Ben Johnson substantially changed the way root canal preparation was accomplished. These instruments made it possible to create an appropriately flared canal shape without the need for time-consuming serial stepback shaping procedures. This instrument sequence allowed greater predictability in canal shape allowing earlier and deeper penetration of irrigating solutions and increased flow dynamics when using thermoplasticized obturation materials.

Profiles are proportionately sized nickel-titanium "U-shaped" instruments marketed by Dentsply. They are designed for use in a controlled, slow-speed, high torque rotary handpiece as well as hand instrumentation.

PROFILE-SERIES 29

The design of the original ProFile instruments was considerably different from the ISO hand file specification as the tip size corresponded to a uniform increase of 29 percent between instruments. Accordingly, the nomenclature of each instrument in the series ranged from 2 to 10. The rationale behind this shift provided the operator with more instruments of smaller tip size to be used in the delicate apical area, while fewer larger instruments were necessary coronally, where flexibility is of less concern. The series also decreased the number of instruments used in canal preparation.

These Series 29 ProFiles (Dentsply Tulsa Dental) were introduced in 1993 with a 0.04 taper, while instruments with 0.06 taper were added later. In due course, a more traditional ISO series of ProFile instruments with conventional sizes was manufactured and marketed by Dentsply Maillefer (Ballaigues, Switzerland) along with a series of Orifice Shapers. The latter instruments are similar to ProFile but, in general, have large tip diameters, shorter cutting blades and greater tapers. Later, ProFile instruments with a 0.02 taper were introduced to provide a comprehensive range of tapers that are capable of dealing with most canals shapes.

- This series of instruments were introduced by Stephen Buchanan .The new size-1 Profile 29 series corresponds to ISO size 10.
- Profile series 29 instruments manufactured in stainless steel have a constant increase of 29 percent in D1 tip diameter.
- 13 instruments replace 20 in the ISO series.
- The first five instruments in the new series are all narrower at D1 than their counterparts in the ISO series.
- They are available in stainless steel and Ni-Ti hand instruments and resemble original engine driven Ni-Ti "U" files.

1. PROFILE 0.04 AND 0.06 TAPER ROTARY INSTRUMENTS (FIG. 12.27)

The preferred range of speed is 275 to 325 rpm.

Mode of Action

These tapered instruments are rotated and produce an accelerated step-down preparation, resulting in a funnel from taper from orifice to apex.

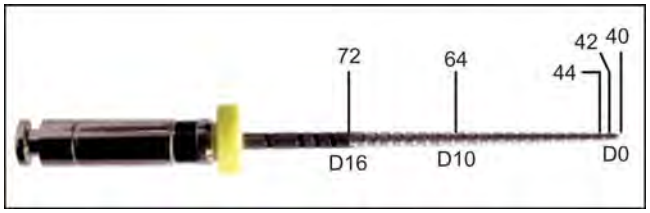


Fig. 12.27: ProFile instrument

These "reamers" rotate clock wise to remove pulp tissue and dentinal debris and travel in anticlockwise back up the shaft. As a result these instruments require periodic removal of "dentin mud" that has filled the "U" portion of the file.

Design (Fig. 12.28)

The U-blade design is similar in cross-section to the light speed. It has flat out edges that cut with a planning action allowing it to remain more centered in canal compared to conventional instruments. It has a 600 bullet nose tip that smoothly joins the flat radial lands. They are cut deeper to add flexibility and help create a parallel inner core of metal. Thus, when the ProFile shaft is rotated, stress becomes more evenly distributed along the entire instrument in contrast to a nonparallel core or tapered shaft of a conventional instrument in which stress are more concentrated towards the tip of its narrow end.

Although these tapers have a 900 cutting angle, the non-aggressive radial landed flutes gently plane the walls without gouging and self threading.

Available as:

- The Profile variable taper instruments are manufactured in standard ISO sizing as well as series 29 (every instrument increases 29 percent in diameter).
- Profile instruments are available in either 0.04 (double taper) suitable for small canals and apical regions of most canals or 0.06 (triple taper) recommended for the mid root portions of the most canals.

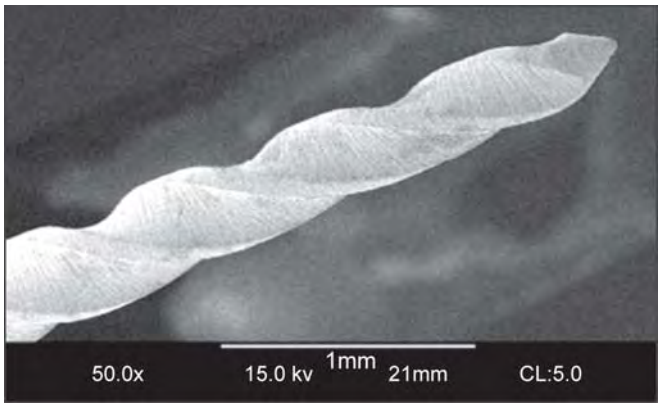


Fig. 12.28: SEM of profile instrument showing radial lands and safe-ended tip

Advantages

- Safety feature in design: They unwind and then wind up backward prior to breaking.
- Stresses become more evenly distributed along the entire instrument in contrast to non-parallel core or tapered shaft of a conventional instrument in which stresses are more concentrated towards the tip of its narrow end.
- 0.06 tapers improve canal shape.
- Due to pronounced taper of these instruments, canal is shaped quickly, efficiently working from coronal section towards the apical section.
- Area of contact with canal walls is small, therefore the contact pressure is high and this gives the instrument greater cutting efficiency.

ORIFICE SHAPERS (FIG. 12.29)

- They are designed to replace Gates-Glidden drills. They are available in 0.06 and 0.07 tapers. They are available with radial lands and U-shaped file design which helps in self centering. They are used for shaping the coronal portion of canal.
- This preflaring allows for more effective cleaning and shaping of apical half of the canal with the profile series 0.04 tapers.

CANAL PREPARATION

Once access, canal patency, and an estimated working length have been determined (Fig. 12.30).

- No: 30, 0.06 taper orifice shaper is taken several millimeters into canal thus creating pathway for next instrument
- No: 50, 0.07 taper orifice shaper is then used to crater more coronal flare followed by No: 40, 0.06

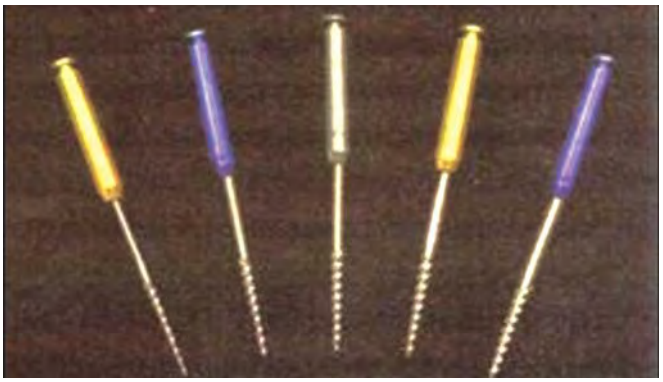


Fig. 12.29: Orifice shapers

	Small canal	Medium canal	Large canal	Instrument depth
Coronal flaring profile O.S.	# 3 06 40 # 2 .06 30	# 4 .07 50 # 3 .06 40	# 5 .08 60 # 4 .07 50	Coronal third
Crown-down sequence	.06 25 .06 20 .04 25 .04 20	.06 30 .06 25 .04 30 .04 25	.06 35 .06 30 .04 35 .04 30	EWL - 3 mm
Working length determination	K-file used in conjunction with apex locator, verified radiographically			
Apical preparation	.04 20 .04 25 up to size of MAF	.04 20 .04 25 up to size of MAF	.04 30 .04 35 up to size of MAF	WL
Final flaring	.06 20 Larger tip size if necessary	.06 25 Larger tip size if necessary	.06 30 Larger tip size if necessary	WL

Fig. 12.30: Canal preparation using profile 0.04 and 0.06 and orifice shapers

taper orifice shaper. This last instrument should be advanced half way down the canal using minimal pressure.

- Working length is taken with stainless steel file.
- Now 0.04 or 0.06 taper Profiles are advanced passively till working length.
- As the rotary reamer moves close to length, a funnel shape is imparted to the canal walls.
- If the tapers are not taken to full working length hand files are used to complete the apical 1 to 2 mm.

PROSYSTEM GT INSTRUMENTS (FIG. 12.31)

GT instruments are available in four basic categories of sizing, the 20 Series (Fig. 12.32), the 30 Series, the 40 Series, and the 0.12 Accessory Series. The 20, 30, and 40 Series GT Files have the same tip diameters in each file set but vary by their designated tapers (0.04, 0.06, 0.08, and 10 mm/mm). The 0.12 Accessory GT files vary by their tip diameters and have a constant rate of taper within the file set, namely 0.35, 0.50, 0.70, and 0.90 mm—all with a large 0.12 mm/mm taper.

GT instruments are also available in hand form (Fig. 12.33), in sizes 20-0.06, 20-0.08, 20-0.10, 35-0.12, 50-0.12, and 70-0.12. The number of black bands on the shank-ends, times two, equals the taper of the file.

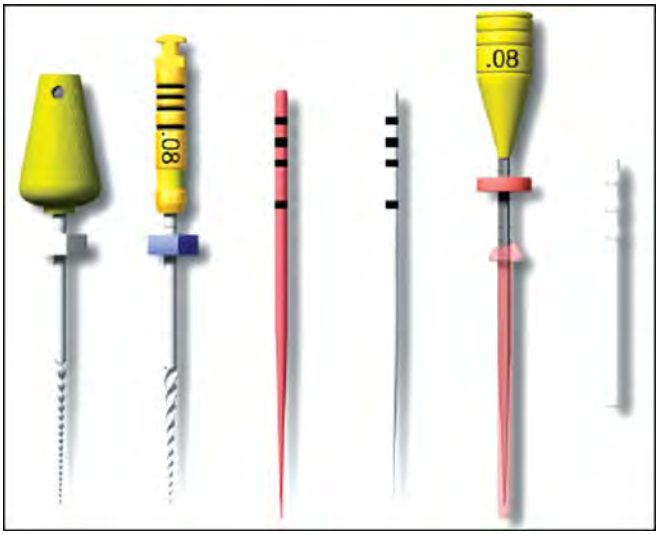


Fig. 12.31: GT set

The color bands on the shanks (or handle color in the case of GT Obturators) indicate the tip diameters in the ISO convention.

Design (Fig. 12.34)

GT instruments are the only taper-centric shaping instruments available, meaning that they vary primarily by their tapers, rather than by their tip

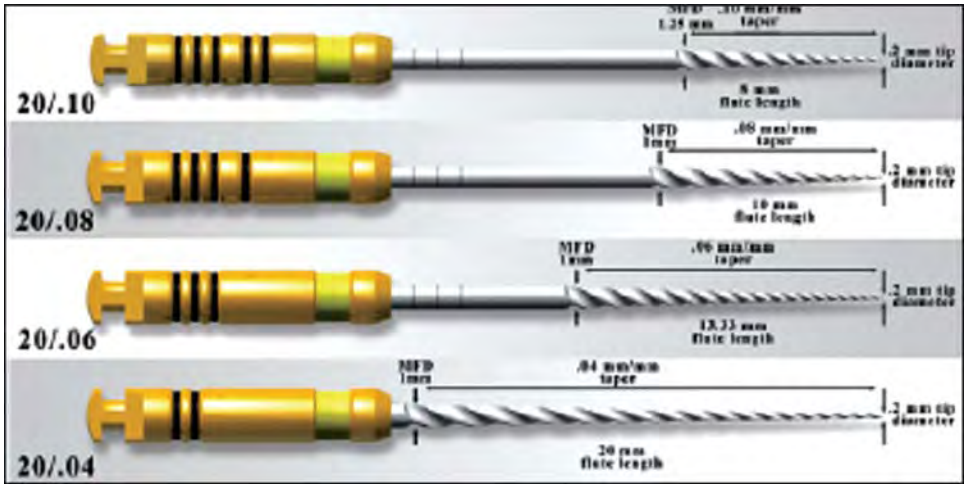


Fig. 12.32: Series GT files. Note how the tapers vary but the tip and maximum flute diameters are constant through the series of files

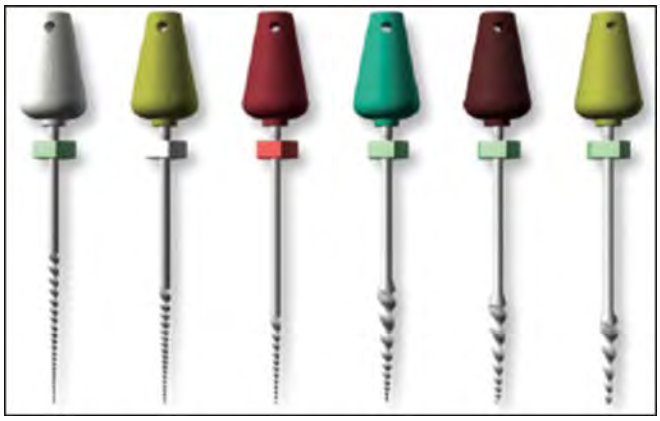


Fig. 12.33: GT Hand instruments

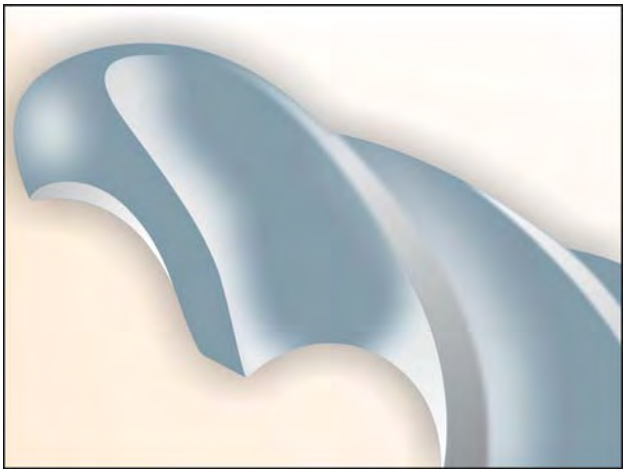


Fig. 12.34: Tip geometry of GT rotary file with non-cutting tip and landed flutes

diameters. GT instruments have limited maximum flute diameters (MFDs), allowing a wide range of tapered instruments to be safely taken to full length in root canals, rather than stepping increasingly larger instruments further back from the canal terminus. Because of their cutting flutes being limited to safe diameters, GT instruments can be used to full length in canals. GT Files have passive rounded tip geometry that dramatically reduces the chances of apical ledging. The cutting flutes of GT instruments are landed, adding further safety in apical regions of canals. GT instruments have variable-pitch flutes, meaning that the flute angles, relative to the long axis of the file, are different along their length.

Mode of Use

- Buchanan recommends that one should start with 0.10 instrument to flare out the coronal third of the canal. This means that this instrument is an ISO size 20 at the tip; but taper is 0.10 mm/mm. It establishes a wider freedom for instruments.
- The instrument is used in a twisting motion, first counter clockwise and then clockwise with apical pressure and then retracted.

Applications

- The 0.06 taper is designed for moderate to severely curved canals in small roots.
- The 0.08 taper is designed for straight to moderately curved canals in small roots. The 0.08

file is best for lower anterior, multirooted premolars and the buccal roots of the maxillary molars, single canal premolars, mandibular canines and maxillary anteriors.
- The 0.10 taper is designed for straight to moderately curved canals in large roots.
- A set of accessory GT files are available for unusually large root canals having apical diameters greater than 0.03 mm.

Advantages

- They have a constant ISO non-cutting tip diameter of 0.20 mm to ensure maintenance of a small apical preparation.
- Open flute angles tend to reduce the file's ability to thread onto the canal.
- Limiting coronal enlargement.

Canal Preparation using Profile GT Rotary Instrument

Profile GT technique can be divided into three steps:
- Step down with ProFile GT
- Step back with ProFile 0.04 taper files
- GT accessory files to create final canal shape
  - Step down approach is used once initial negotiation is completed with hand files.
  - GT files 0.12, 0.10, 0.8 and 0.6 tapers are then used in step down manner at 150-300 rpm.
  - Working length is determined once it has reached two thirds of estimated length.
  - In some cases 0.06 taper will reach full length. Since the standard GT files all have 0.20 mm tip diameter, the 0.08 and 0.10 taper files should easily go to length if 0.08 or 0.10 taper is desired for that canal.
  - Rather than using GT file to the apical terminus, profile 0.04 taper in sizes 25 to 35 are used in step back manner starting 2 mm short of working length.

The standard GT file can then be used to shape apical 2 mm of the canal. If additional coronal flare is needed, GT accessory file can be used.

RAPID BODY SHAPERS

Rapid Body Shaper (RBS) (Moyco/Union Broach; Bethpage, N.Y.) consists of a series of four nickel-titanium rotary engine reamers. These instruments feature the patented nonledging Roane bullet tip and allow the practitioner to rapidly shape the body of the canal without the problems that occur while using Gates-Glidden drills. The RBS instruments develop a parallel-walled canal shape. The RBS series consists of four instruments: No. 1 (0.61 mm at the tip), No.2 (0.66 mm at the tip), No.3 (0.76 mm at the tip), and No. 4 (0.86 mm at the tip).

Canal Preparation

Prior to using RBS, the apical region of the canal must be prepared with a minimum No. 35 ISO instrument to within 0.5 mm of the apex. The No. 1 RBS is then placed in a gear-reduction, slow-speed handpiece at 275 to 300 rpm and allowed to track down the canal 2 to 3 mm. Constant and copious irrigation is necessary at all times. The RBS is removed to clean the fluting and is reinserted to track another 2 to 3 mm down the canal. This sequence is repeated until the No. 1 RBS is within 4 mm of the apex. The No. 2 RBS is then used like the No. 1, also to within 4 mm or shorter form the apex. The No. 3 RBS, followed by the No. 4 RBS, is used to within 7 mm of the apex, completing the body shaping. The No.1 RBS will feel very aggressive, whereas the No. 2 through 4 RBS feel almost passive in comparison. Apical refinement is subsequently completed by hand instruments or via Pow-R nickel-titanium rotary instruments.

Pow-R Nickel-Titanium Rotary Files (Fig. 12.35)

Pow-R Nickel-Titanium Rotary Files (Moyco/Union Broach; Bethpage, N.Y.) are available in 0.02 and 0.04 tapers and Pow-R Coronal shapers are available in 0.08 and 0.06 tapers.

These instruments come in standard ISO instrument sizes as well as in half sizes 17.5, 22.5, 32.5, and 37.5 for more precise apical refinement. They follow standard ISO color codes as well.

They have a nonledging Roane bullet tip and owing to their taper design, allow the practitioner to clean and shape the middle and apical regions of the canal in a conservative manner.

Canal Preparation

Once Gates-Glidden drills are used to prepare and shape the coronal region of the canal in a step-down manner, and the canal has been at least partially

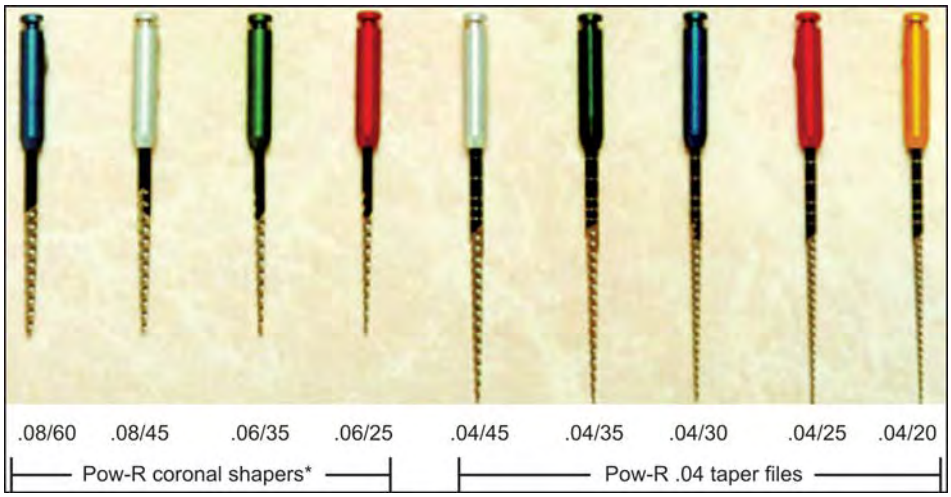


Fig. 12.35: POW-R coronal shapers and files

negotiated with hand files, Pow-R files can be used. The clinician should select a file that binds at its tip in the middle third and begin to gradually move and push that file as it is rotating, slightly withdrawing it at every 0.25 mm penetration until no more than 2 mm of depth is achieved or until resistance is felt. Like any other nickel-titanium file, these instruments must be used passively and with a light touch or pecking motion. The working length should now be determined using a hand file. Constant recapitulation with hand files is the rule along with constant irrigation. The next smaller Pow-R file is used to continue shaping an additional 1 to 2 mm deeper. Rotary instrumentation continues decreasing sizes in sequence until the shaping is about 1.5 mm short of the apical foramen. The remaining portion of the canal can be finished with hand instruments or with Pow-R files. If more flare is needed, particularly if an obturation technique that requires deep condenser penetration is considered, a rotary incremental step-back can be used to generate additional space in the apical and middle portions of the canal.

Both the RBS files and Pow-R instruments are used in high-torque, gear-reduction handpieces with rpm ranging form 300 to 400.

QUANTEC SYSTEM

Quantec Hand Files

These were first designed by Mc Spadden and have undergone many modifications .Quantec instruments are more reamer like than files. The recommended technique for hand instrumentation is divided into three steps—Negotiation, shaping and apical preparation. The tapers ranges from 0.02 through 0.06 with ISO tip sizing. The Quantec Flare Series with increased tapers of 0.08, 0.10 and 0.12 all with tip sizes of ISO 25 are also available.

Quantec Rotary Files (Fig. 12.36)

The Quantec series are marketed by Sybron Endo and Analytic.

Quantec series consists of 10 graduated Ni-Ti tapers from 0.02 through 0.06 with various ISO tip sizes. Quantec Flare Series have increased tapers of 0.08, 0.10 and 0.12, all with tip sizes of ISO 25. They

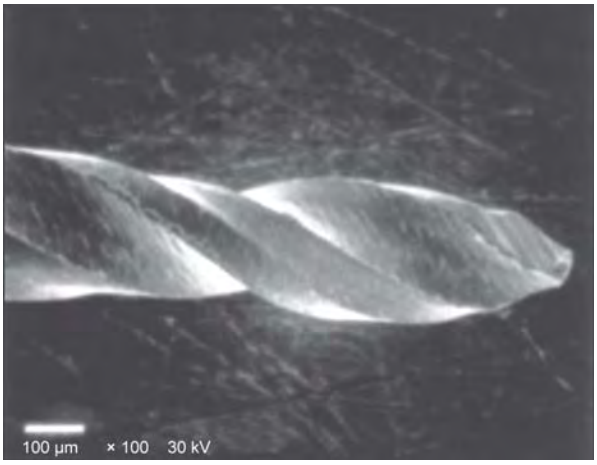


Fig. 12.36: Quantec file

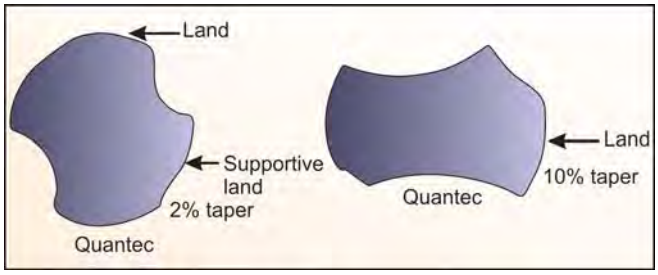


Fig. 12.37: Cross-section of quantec

are designed to quickly and safely shape the coronal third of canal.

Design (Fig. 12.37)

The Quantec rotary instruments are uniquely engineered with slightly positive rake angles on each of their flutes, are designed to shave rather than scrape dentin. Flute design includes a 30-degree helical angle with flute space that becomes progressively larger distal to the cutting blade. More peripheral mass has been added to these files rather than depending on core strength alone as in other rotary systems.

Wide radial lands are purported to prevent crack formation in the blades and aid in deflecting the instrument around curvature. By recessing the radial lands behind the blade, there is a concomitant reduction in frictional resistance while maintaining canal centering.

With respect to tip geometry, the clinician has a choice of two designs.

i. SC—safe cutting tip
ii. LX—Non-cutting tip

i. SC—Safe Cutting Tip

- SC—safe cutting tip is specially designed for small, tight canals, narrow curvatures and calcified canals.
- This faceted 60-degree tip cuts as it moves apically. As the tip approaches a curve, conceptually, a balance takes place between file deflection and cutting.

ii. LX—Non-Cutting Tip

- It is non-faceted bullet nosed tip which acts as a pilot in the canal and deflects around severe curvatures in less constricted canals.

They are recommended for enlarging the body and coronal segments and managing delicate apical regions.

The instruments are used at 300-350 rpm in a high-torque, gear reduction, slow speed handpiece.

Advantages

The efficiency of canal preparation is maximized by restricting surface contact.

Canal Preparation

The Graduating Tapers Technique involves a modified step-down sequence, starting with a larger tapered file first and progressing with files of lesser taper until working length is achieved. The technique involves canal negotiation, canal shaping, and, finally, apical preparation. As in all instrumentation techniques, straight-line access to the canal orifices must be made first followed by passive negotiation of the canal using No.10 and No. 15, 0.02 taper hand files. A Quantec No.25, 0.06 taper, 17 mm in length, is passively used. In most cases, this instrument should approach the apical third of the canal; at this point, the working length must be established.

A glide path is now established for all subsequent quantec files by working No.10 and No.15, 0.02 taper hand files along with sodium hypochlorite to the established working length. During the shaping phase, each Quantec file, progressing sequentially from a 0.12 taper down to a 0.02 taper, is passively carried into the canal as far as possible. In all cases, light apical pressure must be applied, using a light pecking motion and never advancing more than 1 mm per second into the canal. Each instrument should be used for no more than 3 to 5 seconds. The sequence is repeated until a 0.06 or 0.05 taper reaches the working length. The apical preparation can then be deemed complete or further enlarged by using the Quantec standard 0.02 taper No. 40 or No. 45 rotary instruments or hand files.

With the Quantec series, the correct amount of apical pressure must be maintained at all times. The continuously rotating instrument should either be inserted or withdrawn from the canal while allowing for its slow apical progression. The instrument, however, should be withdrawn after the desired depth has been reached and not left in the canal, which may cause transportation, ledge formation, or instrument separation. Thus, to reduce procedural problems, there

should always be a continuous apical/coronal movement of the instrument, and, if the rotating file begins to make a clicking sound (file binding), one should withdraw the file and observe for instrument distortion.

HERO-642

This instrument has a different design from earlier successful rotary instruments. Hero-642 has a trihelical hedstrom design with rather sharp flutes (Figs 12.38 and 12.39). There is increased distance between flutes. There is a change in the helical angle of the flutes and hence reduced risk for binding in the root canal. Hero-642 is designed to operate at 500-600 rpm.

HERO Shapers (Micro-Mega) are designed with the same triple-helix cross-section. The key modification in this instrument involves the pitch of the blade and the length of the cutting portion, which vary depending on the taper. By modifying these parameters, it is possible to select the strength, efficiency, and flexibility best suited for the taper and the work required of the instrument—this is the "Adapted Pitch" Concept.

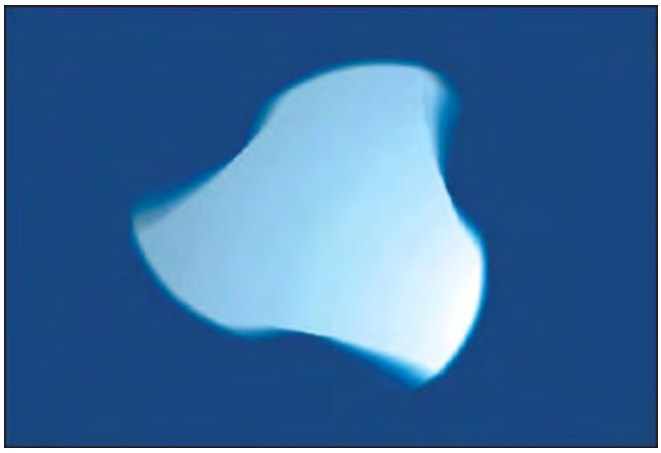


Fig. 12.38: Shape of the blades of the HERO shapers (cross-section)

Fig. 12.39: Tip of the HERO shapers: The tip is inactive and serves to guide the file, keeping it centered in the canal

Two instruments with different tapers (0.06 and 0.04) and three tip diameters (#20, #25, and #30) are used in the HERO Shapers sequence (Figs 12.40A and B). All have a triple-helix cross-section with a positive cutting angle.

Increasing the blade pitch changes the properties of the instrument and thus its behavior during continuous rotation:

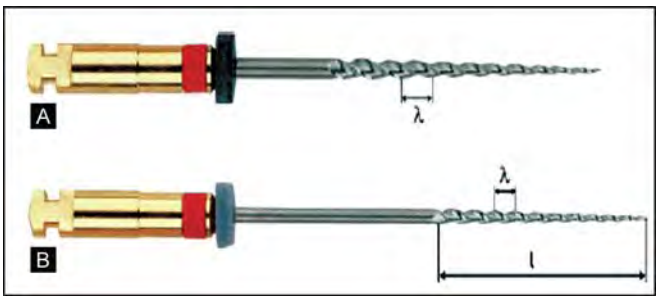
- The longer the pitch, the greater the flexibility
- The smaller the blade angle, the greater the cutting efficiency. Under identical working conditions, rotation speed, and pressure, an instrument with a long pitch will shape a canal more quickly than an instrument with a short pitch.
- Debris evacuation, i.e. dentinal chips, is facilitated by the longer pitch because evacuation is more direct.
- The threading-in phenomenon is reduced.

Choice of Sequence

The operating sequence is chosen as a function of the difficulty of the clinical case and is based on two criteria:

1. The diameter of the root canal (narrow or large).
2. Canal curvature (slight or pronounced).

Preoperative radiographs are used for a preliminary evaluation of the clinical case. A second, more specific evaluation is obtained during the initial negotiation with a conventional hand file.



Figs 12.40A and B: HERO shapers #25 (25/100 tip diamter) with 0.06 (A) and 0.04 (B) tapers. To facilitate access to the canal, a 21-mm-long file with a 0.06 taper should be used, when possible

Three different sequences are recommended:

For simple cases, a single sequence using two #30 files with decreasing tapers is recommended, the first with a 0.06 taper and the second with a 0.04 taper. The small canal curvatures and sufficiently large canal lumen allow a #15 K-file to penetrate to the apex.

Intermediate cases are prepared using the #25 files with 0.06 and 0.04 tapers are followed by a #30 file with a 0.04 taper. Canals of average difficulty have a moderate curvature and more pronounced mineralization of the canal lumen. Penetration with a #10 K-file to the apex may be difficult.

Difficult cases are treated using the. #20 files with 0.06 and 0.04 tapers followed successively by a #25 file with a 0.04 taper and a #30 file with a 0.04 taper to full working length.

RACE (REAMER WITH ALTERNATIVE CUTTING EDGES)

It consists of 16 instruments. It is triangular in cross sectional design with a non-cutting tip. It has unique alternative sharp cutting edges. This eliminates screwing-in and blocking-in action to decrease working torque. Chip dislodgement may be noticed due to its sharp cutting edges.

Instrument Design (Fig. 12.41)

In 1999, 10 years after the first NiTi instruments were introduced, the RaCe system became available; it had a number of new features:

Fig. 12.41: Design of the reamer with alternating cutting edges file (SEM): twisted areas alternate with straight parts. The surface is very smooth because of a special chemical treatment

1. Twisted areas similar to conventional files alternating with straight areas, to giving a larger space for debris and to reduce the tendency to thread.
2. Sharp cutting edges resulting from a square cross sectional shape in the small instruments (15/0.02 and 20/0.02) and a convex triangle (similar to ProTaper or FlexMaster in the remaining RaCe instruments.
3. Reduced active cutting regions on some instruments (9-16 mm).
4. The two largest instruments (35/0.08 and 40/ 0.10) are available in NiTi and stainless steel, the latter being more efficient.

FLEX MASTER

FlexMaster (FM) nickel-titanium files manufactured by VDW, Munich, Germany, have been used in Europe successfully for some time.

Design (Fig. 12.42)

The blades of Flex Master instruments do not have radial lands facilitating effective removal of dentine. Cross-sectional profile of Flex Master is convex, thus increasing in the inner core which reduces the torsional loading and risk of instrument breakage and deformation. Flex Master instruments have a non-cutting

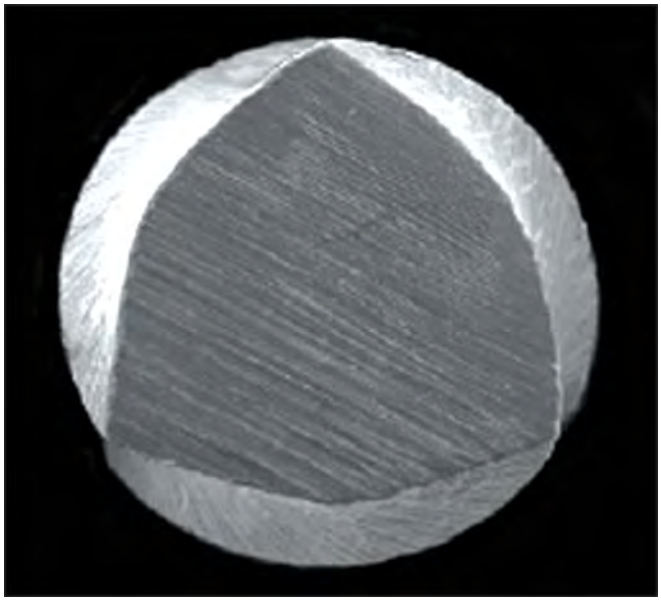


Fig. 12.42: Cross-sectional geometry of FlexMaster

Fig. 12.43: FlexMaster file set

rounded guiding tip which prevents the creation of zip and elbows. A low rotational speed of 280 rpm is recommended for Flex Master.

Availability (Fig. 12.43)

The files are available in ISO sizes 15-70. The taper of 2 percent, 4 percent and 6 percent, respectively, is marked with milled rings on the shank of the instrument. The available lengths are 21, 25 and 31 mm. For individual length marking, all instruments are supplied by the manufacturer with a rubber stop. Calibration on radiographs is assisted by additional depth markings at 18, 19, 20 and 22 mm on the instruments.

Canal Preparation

Preparation commences with the IntroFile, which has a taper of 11 percent and a 9-mm long, active working section. This permits rapid tapered preparation of the canal entrances as well as shaping of the coronal third of the canal. Preparation of the middle third of the canal is completed with one of three simple sequences for large canals (blue sequence), medium canals (red sequence) or narrow canals (yellow sequence). Apical preparation is performed on completion of the crown down phase using files with increasing diameters (green sequence).

FM instruments are among the most comprehensively investigated rotary NiTi instruments. Very good results have been reported both in numerous ex vivo studies and in a clinical setting. Use of Flex Master files was reported to save 20-50 percent of the time invested in manual preparation. Correct preparation lengths were also achieved significantly more often than with manual preparation. Several studies have confirmed the retention of the original shape of the root canal.

Fig. 12.44: ProTaper files

PROTAPER SYSTEM (FIG. 12.44)

This instrument system consisting of three shaping and three finishing files was co-developed by Dr Clifford Ruddle, John West, Pierre Mactou, and Ben Johnson and was designed by Francois Aeby and Gilbert Rota of Dentsply/Maillefer in Switzerland.

The following improvement in design characterize ProTaper system.

- Progressive taper (3.5-9%)
- Modified guiding tip
- Varying tip diameters
- New cross-section of instruments
- Varying helical angle and pitches
- New shorter handle of the file.

Available as (Fig. 12.45):

- The ProTaper system consists of only six instrument
- Available as hand and rotary system.
  Sizes - Three shaping files and three finishing files.

i. Shaping Files

The shaping files are labeled as:
S-X
S-1
S-2

Fig. 12.45: ProTaper rotary files

Shaper-X (S-X)

- This auxiliary instrument used in canals of teeth with short roots or to extend and expand the coronal aspects of the preparation. It is similar to Gates Glidden drills or orifice openers.
- The S-X has a much increased rate or taper from Do (tip diameter) to D9 (9 mm point on blades) than other shaping Protapers (S-1, S-2)
- At the tip (D0) the S-X shapes has an ISO diameter of 0.19 mm. This rises to 1.1 mm at D9, which is comparable to tip size of size 110 ISO instrument.
- After D9 the rate of taper drops off up to D14 which thins and increases the flexibility of the instrument.

Shaper-1 (S-1)

- S-1 starts at the tip size of 0.17 mm.
- It gains in taper up to 1.2 mm.
- Unlike consistent increase in taper per millimeter in ISO instruments, it has increasingly larger taper each mm over 14 mm length of their cutting blades. which makes this instrument unique.
- S-1 is designed to prepare the coronal one-third of the canal.
- S-1 even helps in enlarging middle third of the canal.

Shaper-2 (S-2)

- S-2 file start at tip sizes of 0.20 mm
- It gains in taper up to 1.2 mm
- Unlike consistent increase in taper per mm in ISO instrument it has increasingly larger taper each mm over 14 mm length of their cutting blades.
- S-2 are designed to prepare the middle third in addition to critical region of the apical third.

ii. Finishing Files

- The three finishing files have been designed to plane away the variations in canal diameter in the apical one third.
- The finishing files are designated as:
  a. F-1
  b. F-2
  c. F-3

Finisher F-1

- F-1 have tip diameter D0 of ISO sizes 20.
- The taper differs between D0 and D3. They taper at rate of 0.07 mm/mm
- From D4 to D14 it shows decreased taper that improves its flexibility.

Finisher F-2

- F-2 have tip diameter Do of ISO sizes 25.
- The taper diffes between Do and D3. They taper at rate of 0.08 mm/mm
- From D4 to D14 it shows decreased taper that improves its flexibility.

Finisher F-3

- F-3 have tip diameter D0 of ISO sizes 30.
- The taper differs between Do and D3. They taper at rate of 0.09 mm/mm.
- From D4 to D14 it shows decreased taper that improves its flexibility.
- It has been further engineered to increase its flexibility in spite of its size.

Generally only one instrument is needed to prepare the apical third to working length, and tip sizes (0.20, 0.25 and 0.30) will be selected based on the canals curvature and cross-sectional diameter.

Although primarily designed to finish the apical third of the canal, finishers do progressively expand the middle third as well.

Advantages

1. The progressive (multiple) taper design improves flexibility and instrumentation in curved and restrictive canals.

2. The balanced pitch and helical angles of the instrument prevent threading and optimize cutting action while effectively auguring debris coronally.
3. Both the "shapers" and the "finishers" remove the debris and soft tissue from the canal and finish the preparation with a smooth continuous taper.
4. The triangular cross-section of the instruments increases safety, tactile sense and cutting action.
5. The modified guiding instrument tip can easily follow a prepared glide path without gouging side walls.

Canal Preparation

Protaper system: Guidelines for use:

1. Prepare a straight-line access cavity with no restrictions in the entry path into the chamber.
2. Fill the access cavity brimful with sodium hypochlorite and/or Prolube.
3. Establish a smooth glide path with No. 10 and No.15 stainless steel hand files.
4. Use maximum magnification to observe the movement of the rotary instrument. "Seeing" rotary apical movement is safer than simply "feeling" such movement.
5. Use a torque-and speed-controlled electric motor, powering the handpiece at 200 to 300 rpm.
6. Be much gentler than with hand instruments. Always treat in a moist canal. Irrigate frequently.
7. Each instrument should do minimal shaping. Only two, three, or four passes may be required for the file to engage restrictive dentin and carve the shape to the proper depth.
8. Instruments break when flutes become loaded or when instruments are forced. Check the flutes frequently under magnification and clean them. Cyclic fatigue from overuse, or if the glide path is not well established, also leads to breakage.
9. ProTaper instruments are disposable and, like all endodontic files and reamers, are designed for single-patient use. Sometimes instruments are even changed within the same treatment (e.g. in the case of a four-canal molar).
10. Irrigate with 17 percent EDTA or a viscous chelator during the ProTaper shaping.

ProTaper System: Directions for Use

1. Establish proper access and a glide path with No.10 and No.15 stainless steel files to the working length or the apical constriction.
2. Fil the canal and chamber with sodium hypochlorite and begin shaping with the shaper S - 1 using multiple, passive-pressure passes. Go no deeper than three-quarters of the estimated canal length. Irrigate and recapitulate with a No. 10 hand file, establishing patency to full working length. Now, with S-1, extend the preparation to full working length. Again irrigate and recapitulate.
3. "Brush" with the Shaper S-X to improve the straight-line access in short teeth or to relocate canal access away from furcations in posterior teeth.
4. Shaping file S-2 is now used to full working length. Irrigate, recapitulate, and re irrigate.
5. Confirm and maintain working length with a hand file. (Remember, as curves are straightened, canals are shortened).
6. With finisher F-1, passively extend the preparation to within 0.5 mm of the working length. Withdraw after one second. The F-1 has a tip size of 0.20 mm, and if a No. 20 hand instrument is found to be snug, the preparation is finished. With the instrument in place, radiographically verify the exact length before final irrigation.
7. If the F-1 and the No. 20 hand file are loose continue the preparation with the finisher F-2, which is 0.25 mm diameter at the tip. Confirm with a No. 25 hand instrument and, if snug, confirm the length radiographically, irrigate, and complete.
8. If the F-2 instrument and the No.25 hand file are loose, continue the preparation to just short of the working length with the finisher F - 3 file, which has a 0.30-mm tip diameter and follow with the confirming No. 30 instrument. If the No.30 is found to be snug, the preparation is finished. If this is loose, there are a number of techniques to enlarge the apical third to large sizes.
9. Frequent irrigation and file cleansing are imperative along with recapitulation.

Now that the perfectly tapered preparation is complete, smear layer removal with EDTA and sodium hypochlorite is in order, followed by either medication and/or obturation.

K3 FILE SYSTEM

K3 file system is designed by Dr John Mc Spadden. They are available as K3 canal shaping files and body shaping files.

K3 Canal Shaping Files

- They are available with a fixed taper of 0.02, 0.04 and 0.06.
- 0.02 taper instruments are available in sizes No: 15 through No: 45 in 21, 25 and 30 mm lengths.
- 0.04 and 0.06 taper instruments are available in size No: 15 through No: 60 and 21, 25 and 30 mm lengths.

K3 Body Shaping Files

- They are available in 0.08, 0.10 and 0.12 tapers
- They are available as only size No: 25.
- Different lengths available are 17, 21 and 25 mm.

Instrument Design (Fig. 12.46)

An instrument's cutting efficiency depends on the rake angle of the cutting blades. The ideal rake angle is slightly positive because an overly positive rake angle will result in too active cutting of dentine and probably threading in.

The K3 features an asymmetrical design with a slightly positive rake angle for optimum cutting efficiency (Fig. 12.47).

Wide Radial Lands (Fig. 12.48)

The strength of the file comes from the inner core of the instrument, rather than the peripheral area near the cutting blade. This part of the instrument is also called the radial land. The less blade support (the amount of metal behind the cutting edge) the less resistant the instrument is to torsion stress. The increased radial land of the K3 increases its peripheral strength behind the cutting blade with a positive effect on the instrument's resistance during rotation.

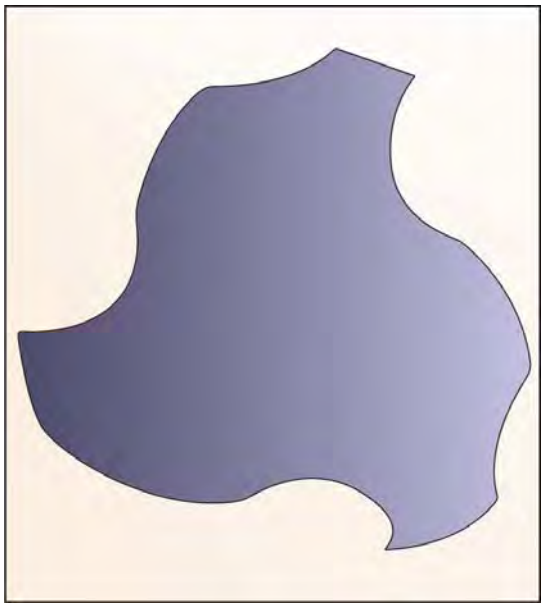


Fig. 12.46: Cross-section of K3

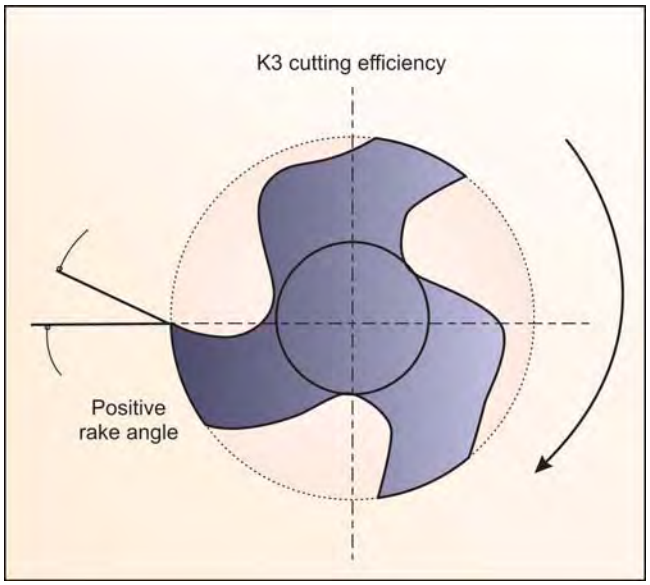


Fig. 12.47: Positive rake angle

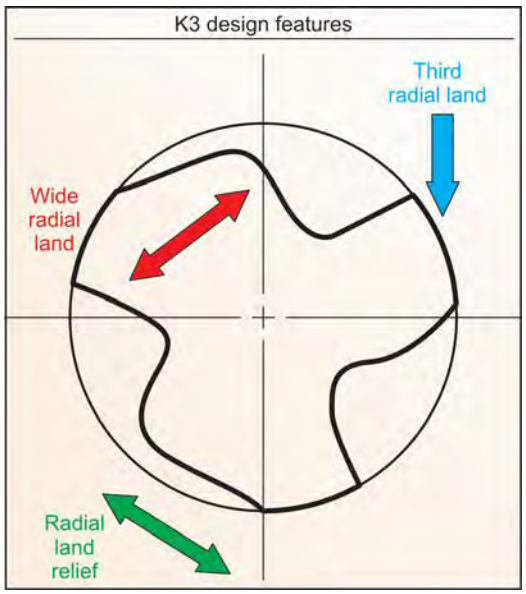


Fig. 12.48: Design features

Peripheral Blade Relief

Peripheral Blade Relief was designed to reduce friction and facilitate smoother operation. It also helps to control the depth of cut. This aids in protecting the instrument from over-engagement, and separation.

Third Radial Land

The primary purpose of the Third Radial Land is to prevent the instrument from threading itself into the canal. This feature allows the operator more control by centering and stabilizing the instrument while rotating.

Variable Helical Flute Angle

Once the instrument has made its cut into the dentine the debris must be removed. Dentine chips resulting from the K3 cutting action are easily dislodged from the working area and carried to the orifice via its unique helical angle. The result is an instrument with unparalleled debris removal.

Variable Core Diameter

This is best described as variable flute depth. The proportion of the core diameter to the outside diameter is greatest at the tip where the greatest strength is needed. This proportion then decreases uniformly towards the shank, resulting in greater flute depth and increased flexibility, while maintaining strength.

Safe-ended Tip (Fig. 12.49)

The non-cutting tip of the K3 instrument helps to follow the canal path while minimizing the risks of ledging, zipping and perforations. This feature also aids in minimizing canal transportation.The tendency to push debris apically is also reduced significantly, thus decreasing patient's postoperative pain.

GUIDELINES FOR INSTRUMENTATION WITH THE PROCEDURE PACK (FIG. 12.50)

1. Obtain straight-line access, locate orifice and obtain patency.
2. Begin crown-down by taking a 0.10 Taper K3 to resistance.
3. Take a 0.08 taper K3 to resistance.
4. Estimate apical size.

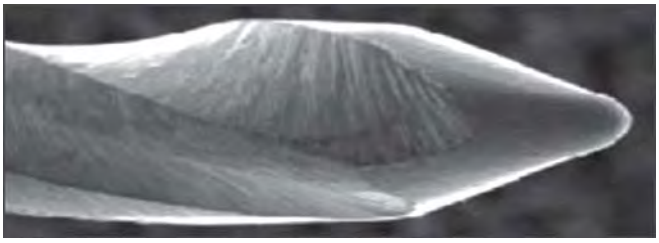


Fig. 12.49: Scanning electromicrograph of K3 safe-ended tip

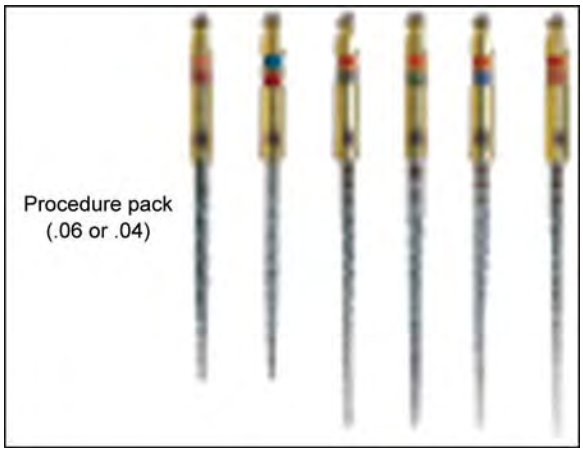


Fig. 12.50: Procedure pack

5. Re-enter crown-down using a size #40 K3 instrument.
6. Establish working length. Establish this with an apex locator. A radiograph must be taken to assist in working length determination and to evaluate canal morphology.
7. Complete the crown-down preparation with a #35 K3 instrument, #30 K3 instrument, #25 K3 instrument, by taking each to resistance at 300-350 rpm in an electric torque control motor. Each instrument should be used for only 5-7 s. The selection between 0.04 and 0.06 tapers is determined by canal anatomy and filling technique.

GUIDELINES FOR INSTRUMENTATION WITH K3 G-PACK (GRADUATING TAPER) (FIG. 12.51)

1. Obtain straight-line access, locate orifice and obtain patency.
2. Begin crown-down by taking the 0.12 taper K3 to resistance (the 0.12 taper K3 is designed to open the orifice only).

Fig. 12.51: G pack

3. Take the 0.10 taper K3 to resistance.
4. Establish working length, as previously described.
5. Take a 0.08 taper K3 Shaper to resistance.
6. Take the 0.06 taper #25 K3 instrument to resistance. Many canals will be completely prepared after this step. In more difficult, curved and narrow canals there is an option of using a 0.04 taper #25 K3 instrument and a 0.02 taper #25 K3 instrument until working length is achieved. Recapitulate back to 0.04, then 0.06 taper, if possible.

Mtwo (Fig. 12.52)

Mtwo NiTi instruments, unlike the NiTi systems presently on the market, continuously shape the entire canal walls while they are progressing in the canal - "Simultaneous Shaping". These are available in sterile blisters of 6 instruments

Mtwo NiTi Instruments are particularly flexible and efficient due to their S-shaped cross-section and two efficient cutting blades. The distance between the cutting blades increases from the tip toward the shaft providing large space for dentin removal. This innovative design reduces to a minimum the adverse screwing effect. Two active cutting edges are extremely efficient and cause only little friction. This makes Mtwo instruments very fracture resistant.

This is a minimally invasive NiTi system with only one sequence based on traditional hand preparation, providing excellent results necessitating not more than four instruments. Irrespective of the canal shape, only one standard sequence is necessary. Additional instruments are available for shaping root canals according to different filling techniques (e.g. vertical condensation).

Fig. 12.52: Mtwo

Mtwo applies the "Single Length" technique; that is, from the beginning of the treatment the dentist always uses the first file to full working length. This corresponds to the traditional hand preparation method. The dentist, as well as the assistant, will have fewer difficulties to switch from hand instrumentation to rotary NiTi preparation. This is a very easy system for crown-down technique.

ENDO SEQUENCES (REAL WORLD)

Endo sequence technology has been designed to generate predictability in obturation through a matching system of laser verified gutta-percha cones, creating synchronicity between a machined preparation and master cone.

Blank Design

They introduced Alternate Contact Points along the cutting surface of instruments.

- This keeps file in the center of canal
- This limits the engagement and decreases torque on the file as it is sharper, less bulky and more flexible.

Tip Design

It uses a precision tip which is non-cutting tip that becomes fully engaged at D1. This results in safety combined with efficiency.

Metal treatment: Historically Ni-Ti instruments have been polished in a drum but they are subjected to a process called "electro polishing". This will remove many of imperfections than can lead to separation. This keeps instrument edge sharper, cleaner and more durable.

- They are available in variable pitch and helical angles which gives more control
- Because of the reamer like design, i.e. alternate contact points and sharp edges it has superior cutting efficiency.
- It is used with rpm of 500-600 rpm.

V-TAPER FILES

V-taper Glide-path System (Fig. 12.53)

The Guidance Glide-Path System is a revolutionary advancement in hand files. The three #10 V-Taper hand files with a variable taper design form a better shaped and more efficient glide-path, enhancing rotary file performance and far exceeding 02 tapered hand files.

Establishes the Glide-path for Small, Medium and Large Canals (Fig. 12.54)

Use: 10 (V02) -> 10 (V04) -> 10 (V06) -> repeat to taper of choice

Always use a lubricant: NaOCl with EDTA. Use each file for less than 10 seconds, and then move to the next file. Establish apical patency for calcified, tortuous, or difficult canals.

V-Taper Rotary System-3-File Set

The V-Taper Rotary System is a set of three variable taper NiTi rotary files. The V-Taper™ Rotary System will allows completion most root canals using 2-3 files. This performance-enhanced system is easier, safer and more efficient,

30 (V10) -> 25 (V08) -> 20 (V06)

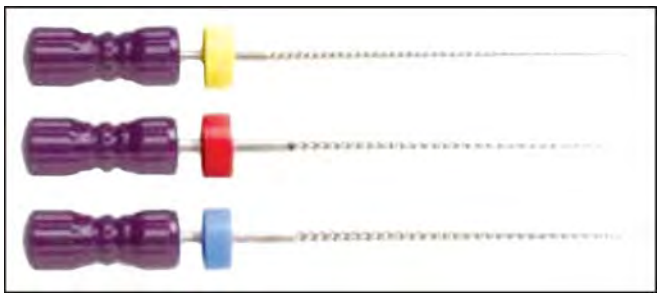


Fig. 12.53: #10 V-Taper Hand Files

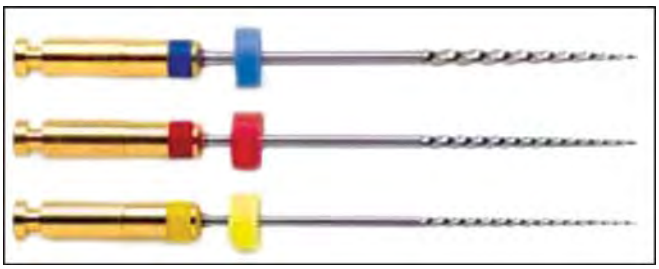


Fig. 12.54: V-Taper Rotary System

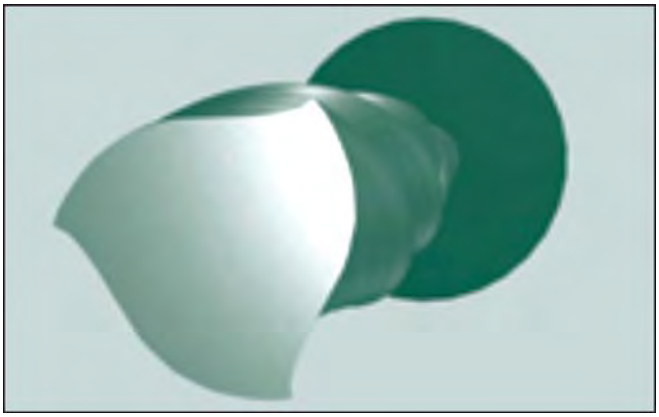


Fig. 12.55: Parabolic cross-section of V-taper

The variable taper rotary file allows the operator to attain deeper apical shapes with fewer instruments and a more conservative access than with any other system. Most cases are completed using 2-3 files. The V-Taper™ Rotary System will result in higher-quality cases which are easier to irrigate and obturate at considerable savings in time and instrument cost.

Design

Safe-Core Parabolic Cross-Section (Fig. 12.55)

It has been shown that the parabolic cross-section is the best design to perform deep drilling and reaming as performed during root canal treatment. The Parabolic Cross-Section combines the attributes of being a highly efficient and flexible cutting instrument with being extremely safe and resistant to fracture.

Symmetric Shape: Prevents excessive stress and strain on the file to make it very resistant to fracture.

No Land: Presence of a land makes an inefficient cutting instrument, causing tremendous drag and friction, which can result in heat build-up in the file. This can result in fractured instruments.

No Excessive Clearance Angle: A triangle-shaped file has a clearance angle over 30 degrees, which is designed to cause a great deal of side cutting and canal transportation. This is avoided in V-taper.

Neutral Rake Angle: A neutral rake angle is a very efficient cutting angle, the best for root canals and deep-hole reaming. A positive rake angle will gouge and grab the canal walls. This gouging and grabbing puts unnecessary torque on the canal and forms "hot spots" on the file, which can result in fracture. A negative rake angle will drag and burnish the walls of the canal, which can result in heat build-up in the file and fractured instruments.

No Reverse Cutting: The parabolic design does not cut or engage in the reverse direction. An electric torque control motor will turn in the reverse direction when the torque limit is reached. A file with a land or triangular cross-section will engage dentin in the reverse direction and place undue stress on the file. This stress can lead to decreased file life and ultimately fracture.

V-Taper file simulates the natural variable taper of the canal. This allows the dentist to complete cases more safely, easily, and quickly, with fewer files.

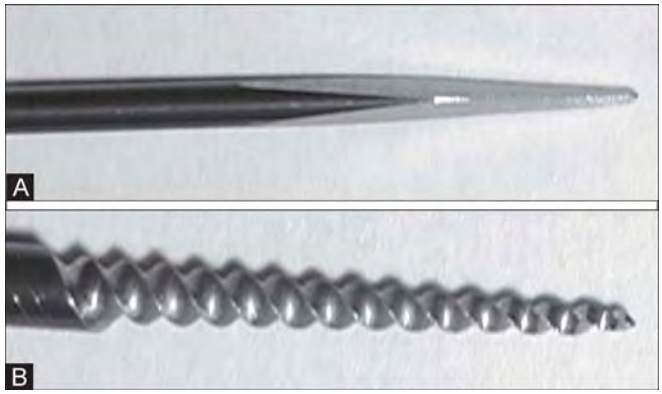
LIBERATOR (FIG. 12.56)

Liberator is a straight fluted file unlike previous files which were helically fluted (Figs 12.57A and B). It is triangular in cross-section, designed to operate at higher speeds.

1. Straight-flute design cannot self-thread
2. Lack of radial land areas reduces friction
3. Higher RPM reduces torque forces
4. Roane safety tip keeps file centered
5. Efficient removal of dentin
6. Manufacturing process eliminates transverse micro-cracks.

1. *Straight-flute design cannot self-thread:* Several studies have shown that self-threading is a precursor to file separation. Since most rotary endodontic instruments are helically-fluted- like a wood screw, they have a natural tendency to self-thread. Liberator rotary NiTi file is a straight-fluted instrument. In a controlled study, Liberator demonstrated 0 percent self-threading.
2. *Lack of radial land areas reduces friction:* Radial land areas are required for conventional helically-fluted files because they prevent the file from over-engagement in the canal. If a file becomes suddenly engaged or self-threaded, it may fracture. Radial lands are especially important for files that have positive rake angles. Liberator rotary files have no land areas. The only friction is the file abrading tooth structure.
3. *Higher RPM reduces torque forces:* Liberator instruments operate at RPMs of 1,000 to 2,000. High RPM offers the benefit of lower torque.
4. *Roane safety tip keeps file centered:* Dr James Roane developed the Roane safety tip that minimizes ledging and transportation. It also helps center the file in canal. This tip design is used on all Liberator NiTi rotary files.
5. *Efficient removal of dentin:* Liberator NiTi rotary files quickly remove dentin because of their sharp cutting blades moving at high velocity.
6. *Manufacturing process eliminates transverse micro-cracks (Fig. 12.58):* Liberator rotary NiTi files are manufactured with using electro-chemical grinding (ECG) techniques.

Fig. 12.56: Liberator



Figs 12.57A and B: Straight flute vs. helical flute

Guidelines to be followed during biomechanical preparation:

1. Direct straight line access should be maintained
2. Instrument should be used in a sequential manner.

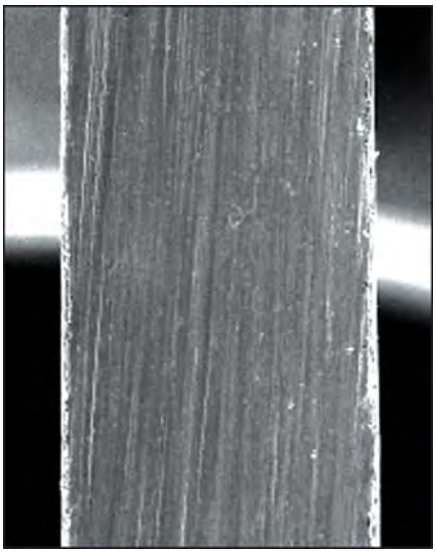


Fig. 12.58: Liberator file parallel grinding pattern (vertical tool marks)

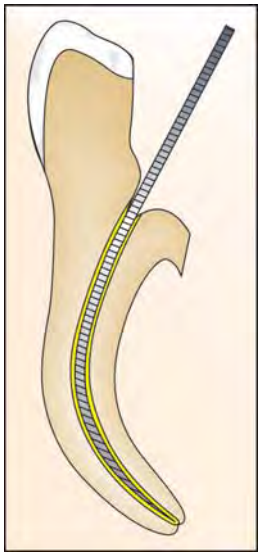


Fig. 12.59: Apical-coronal preparation

3. Instrumentation should always be done in wet canal along with copious irrigation
4. Precurving of stainless steel files to be done while working in curved canals
5. Instruments should always be used with periodic recapitulation.
6. Confine instruments in root canal and do not force debris apically.
7. Instruments should be thoroughly inspected for manufacturing defects prior to their use.

TECHNIQUES FOR PREPARING ROOT CANALS

1. Apicocoronal method
2. Coronoapical method

1. Apicocoronal Method (Fig. 12.59)

a. Conventional method
b. Step back preparation
c. Balanced force technique

Most commonly used method for biomechanical preparation with hand instrumentation. This method is preferable when the canals are straight. This is a relatively easy method to follow with minimum instruments.

Disadvantages:

- Pushing of debris towards the apex
- Alteration of working length

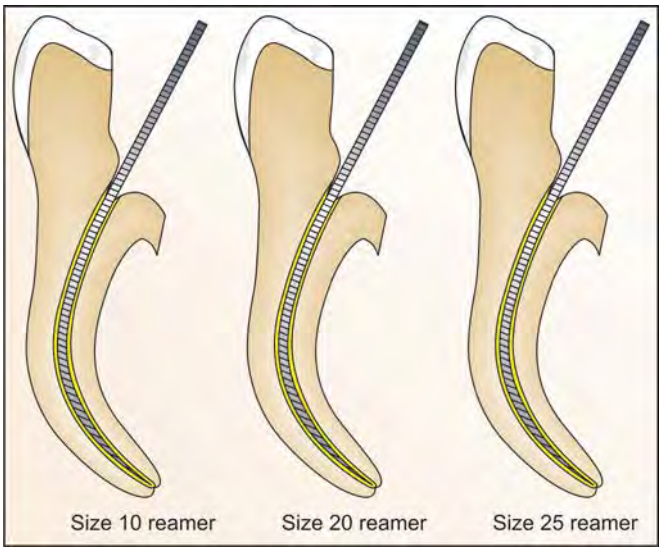


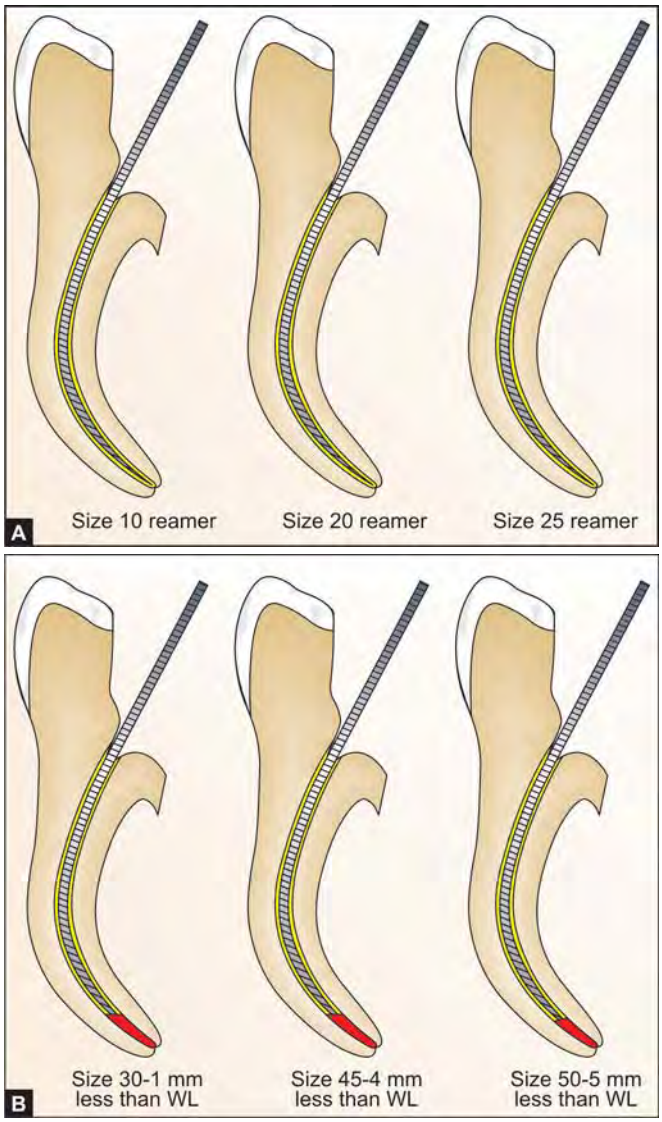
Fig. 12.60: Conventional method

- Difficult to debride complex canals
- Difficult to use in narrow canals except for Roane's balanced force technique
- Vertical root fracture if over instrumentation carried out

a. *Conventional method (Fig. 12.60):*
   1. Determine the working length.
   2. Enlarge the orifices (coronal flaring) using Gates-glidden drills and Peeso-reamers.
   3. Enlarge the canal 3 times the initial width of the canal.

4. At least 1 mm of sound dentine should be present along the periphery of the canal.
5. Instruments are used sequentially with periodic recapitulation.
6. *Recapitulation:* It is an important step especially in apicol-coronal techniques. It means the use of the instruments in the correct size, sequence from smaller to larger and returning to smaller instruments from time to time before advancing to a larger size to prevent accumulation of debris.

b. *Step back preparation (Figs 12.61A and B):* This method is also known as "Telescopic preparation" or "flare method"



Figs 12.61A and B: Step back preparation

1. In this method root canal is enlarged up to minimum size of no. 25.
2. Subsequently larger sized instruments are used short of 1 mm (Suppose if apex is enlarged no. 25, no. 30 instrument should be used 1mm short.
3. Periodic recapitulation is mandatory with this method.

Advantages

- Apical anatomy is maintained facilitating better obturation.

Disadvantages

- Apical blockage
- Alteration of WL
- Tendency for canal deviation.

2. Coronoapical Method (Fig. 12.62)

Instrumentation is carried out from the coronal portion to the apex:

a. Crown down preparation
b. Crown down pressureless technique
c. Double flare technique
d. Canal master U technique (Figs 12.63A to F)

Advantages

1. Debris will be pushed to the coronal side thus minimizing apical extrusion.
2. Initial coronal preparation provides way for the irrigating solutions facilitating better cleaning.
3. The technique can be used in curved canals.

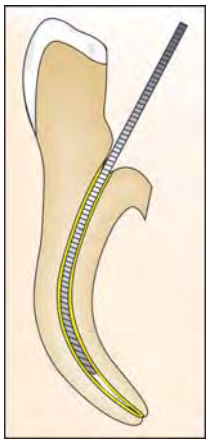
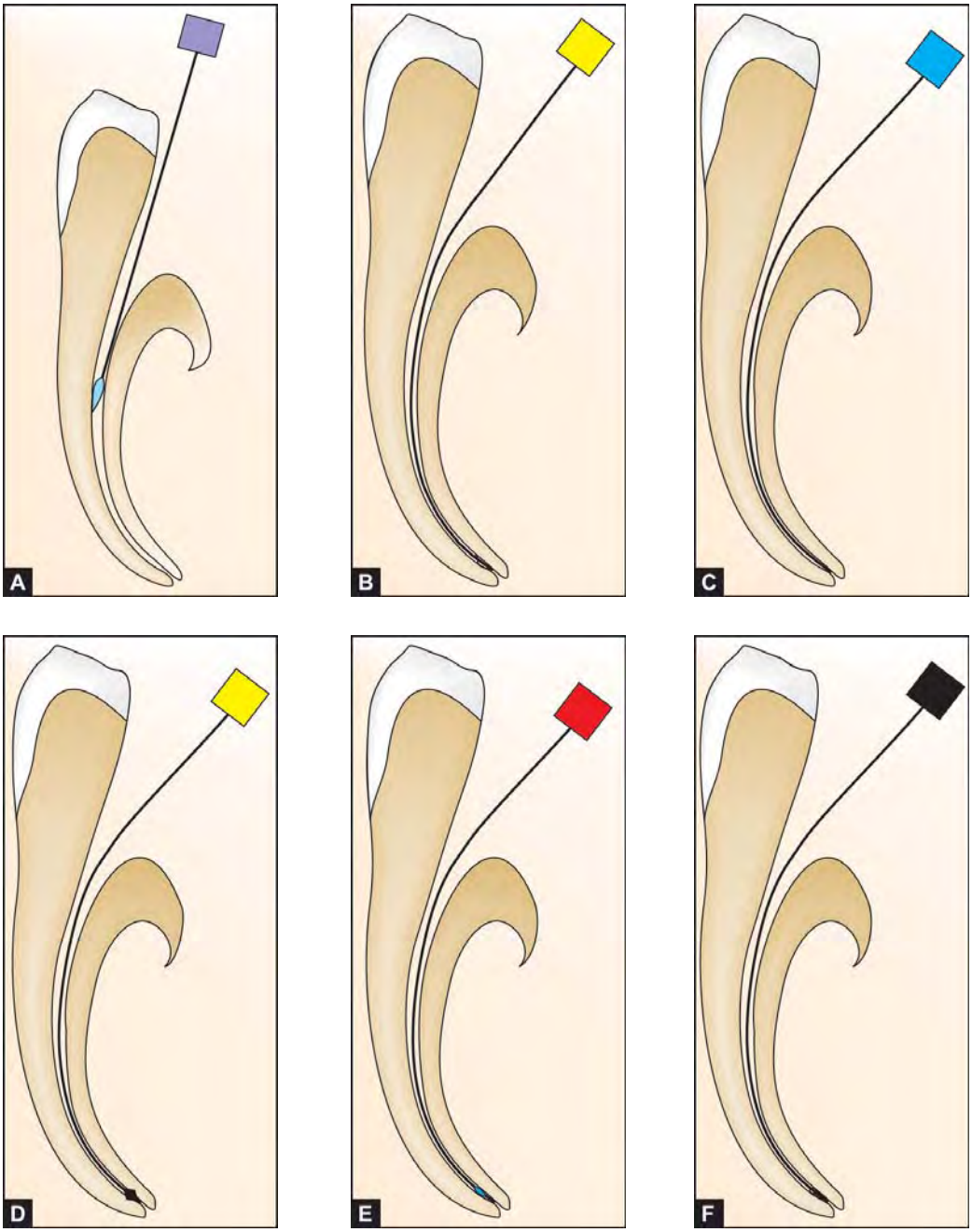


Fig. 12.62: Coronalapical preparation



Figs 12.63A to F: Canal master technique (A) No. 80 to the first curve; (B) No. 20 to working length; (C) No. 30 to working length; (D) No. 50 to working length; (E) No. 55 to working length; (F) No. 80 to working length

CROWN DOWN PREPARATION (FIGS 12.64 TO 12.73)

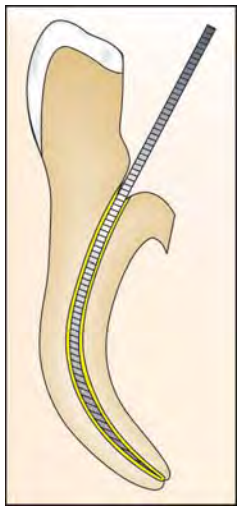


Fig. 12.64: File no 10 to working length

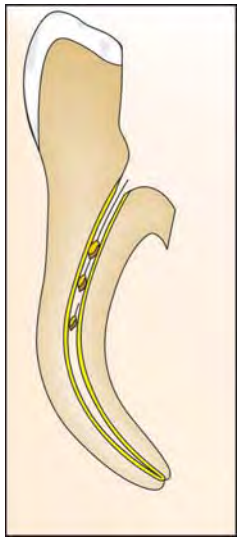


Fig. 12.65: Coronal flaring using GG 3, 2, 1

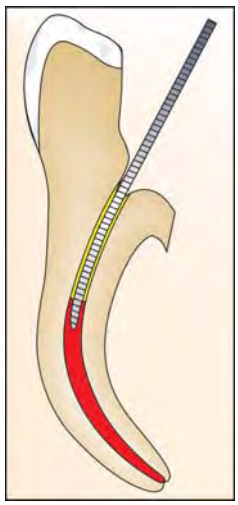


Fig. 12.66: No 35 at 14 mm

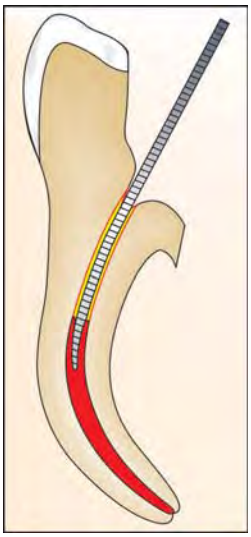


Fig. 12.67: No 30 1 mm deeper

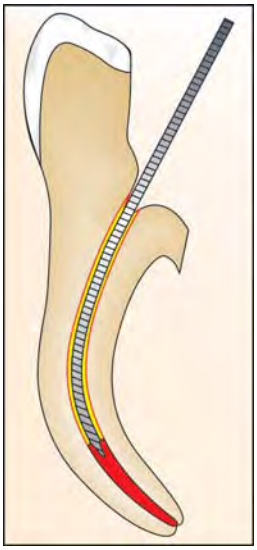


Fig. 12.68: No 25 1 mm deeper than 30

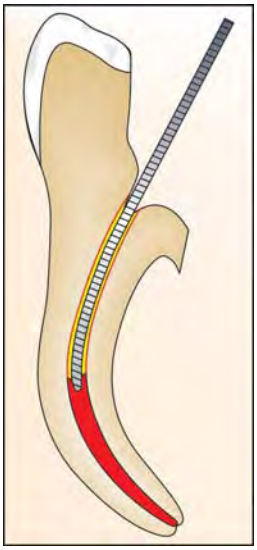


Fig. 12.69: Size 40

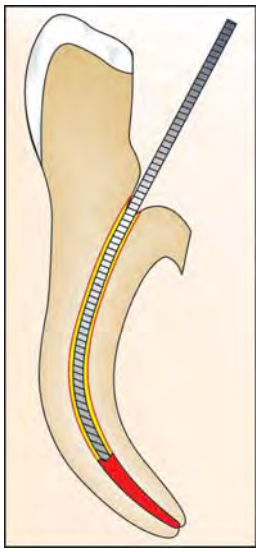


Fig. 12.70: Size 30

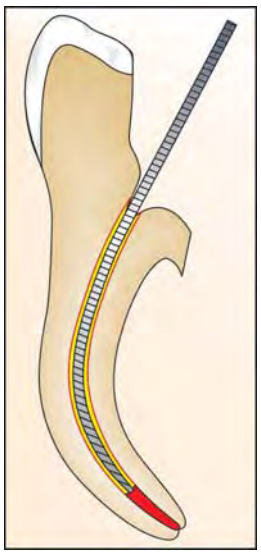


Fig. 12.71: Size 25

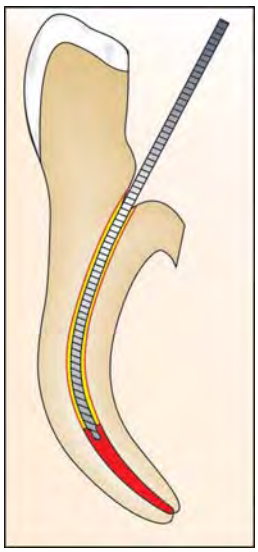


Fig. 12.72: size 35

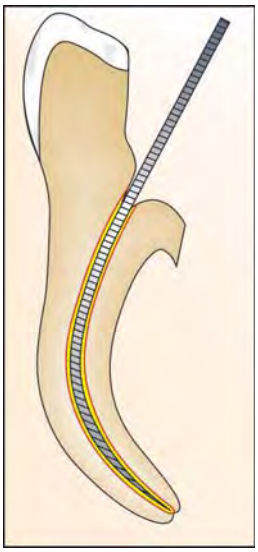


Fig. 12.73: Size 20 till WL

SUGGESTED READING

1. Brockhurst PJ, Denholm I. Hardness and strength of endodontic files and reamers. J Endod. 1996 Feb;22(2): 68-70.
2. Briseno BM, Sonnabend E. The influence of different root canal instruments on root canal preparation: an in vitro study. Int Endod J 1991;24:15-23.
3. Bryant ST, Dummer PMH, Pitoni C, Bourba M, Moghal S. Shapingability of .04 and .06 taper profile rotary nickel-titanium instruments in simulated root canals. Int Endod J 1999;32:155-64.
4. Buchanan LS. The standardized-taper root canal preparation - Part II. GT file selection and safe handpiece-driven file use. Int Endod J. 2001 Jan;34(1):63-71.
5. Christopher JR Stock. Endodontics, second edition. Mosby-Wolfe, Philadelphia.
6. Dautel-Morazin A, Vulcain JM, Guigand M, Bonnaure-Mallet M. An ultrastructural study of debris retention by endodontic reamers. J Endod. 1995 Jul;21(7):358-61.
7. David sonntag FlexMaster: a universal system. Endodontic Topics 2005, 10, 183-86.
8. Dr Joseph Dovgan. Non-surgical endodontics in the new millennium. Endodontic Practice May 2000.
9. Darabara M, Bourithis L, Zinelis S, Papadimitriou GD. Assessment of elemental composition, microstructure, and hardness of stainless steel endodontic files and reamers. J Endod. 2004 Jul;30(7):523-6.
10. E Steve senia, William l wildey. Then Light Speed root canal instrumentation system. Endodontic Topics 2005;10: 148-150. Ferraz CC, Gomes NV, Gomes BP, Zaia AA.
11. Gutierrez JH, Gigoux C, Sanhueza I. Physical and chemical deterioration of endodontic reamers during mechanical preparation. Oral Surg Oral Med Oral Pathol. 1969 Sep;28(3):394-403. No abstract available.
12. Gianluca Gambarini. The K3 rotary nickel titanium instrument system Endodontic Topics 2005;10:179-82.

13. Hulsmann M, Rummelin C, Schafers F. Root canal cleanliness after preparation with different endodontic handpieces and hand instruments: a comparative SEM investigation. J Endod. 1997 May; 23(5):301-06.
14. Kartal N, Cimilli HK. The degrees and configurations of mesial canal curvatures of mandibular first molars. J Endod. 1997 Jun; 23(6):358-62.
15. Kenneth S Serota, Yosef Nahmias. Predictable Endodontic Success: The Hybrid Approach - Part I. May 2003 Oral health.
16. MA Bauman. NiTi: options and challenges. Dent Clin N Am (48) 55-67.
17. MA Bauman. Reamer with alternating cutting edges - concept and clinical application. Endodontic Topics 2005;10:176-8.
18. Michael Hu lsmann, Ove A. Peters and Paul M. H Dummer Mechanical preparation of root canals: shaping goals, techniques and means. Endodontic Topics 2005;10:30-76.
19. Miserendino LJ, Miserendino CA, Moser JB, Heuer MA, Osetek EM. Cutting efficiency of endodontic instruments. Part III: comparison of sonic and ultrasonic instrument systems. J Endod 1988;14:24-30.
20. Nagy CD, Bartha K, Bernath M, Verdes E, Szabo J. The effect of root canal morphology on canal shape following instrumentation using different techniques. Int Endod J 1997;30:133-40.
21. Oliet S, Sorin SM. Cutting efficiency of endodontic reamers. Oral Surg Oral Med Oral Pathol. 1973 Aug;36(2): 243-52. No abstract available.
22. Ove A. Peters and Christine I. Peters. Cleaning and Shaping of the Root Canal System. Cohen"s pathways of pulp 9th edition. 291-356.
23. Paul calas HEROShaperss: the adapted pitch Concept. Endodontic Topics 2005;10:155-62.
24. Peters OA, Scho¨nenberger K, Laib A. Effects of four NiTi preparation techniques on root canal geometry assessed by micro computed tomography. Int Endod J 2001;34:221-30.
25. Ruddle C. Cleaning and shaping the root canal system. In: Cohen S, Burns R, (Eds): Pathways of the Pulp, 8th edn. St Louis, MO: Mosby, 2002;231-92.
26. Segall RO, del Rio CE, Brady JM, Ayer WA. Evaluation of debridement techniques for endodontic instruments. Oral Surg Oral Med Oral Pathol. 1977 Nov;44(5):786-91.
27. Segall RO, del Rio CE, Brady JM, Ayer WA. Evaluation of endodontic instruments as received from the manufacturer: the demand for quality control. Oral Surg Oral Med Oral Pathol. 1977 Sep;44(3):463-67.
28. Schafer E, Tepel J, Hoppe W. Properties of endodontic hand instruments used in rotary motion. Part 2. Instrumentation of curved canals. J Endod. 1995 Oct;21(10):493-97.
29. Scha¨fer E, Schulz-Bongert U, Tulus G. Comparison of hand stainless steel and nickel titanium rotary instrumentation: a clinical study. J Endod 2004;30:432-35.
30. SJ Jardine, K Gulabivala. An in vitro comparison of canal preparation using two automated rotary nickel-titanium instrumentation techniques. International Endodontic Journal, 2000;381-91.
31. Schilder H. Instruments, materials, devices. In: Cohen S, Burns RC, (Eds): Pathways of the Pulp, 6th edn. St. Louis, MO: USA: MosbyYear Book, 1994;386-8.
32. Tinaz AC, Karadag LS, Alacam T, Mihcioglu T. Evaluation of the smear layer removal effectiveness of EDTA using two techniques: an SEM study. J Contemp Dent Pract. 2006 Feb 15;7(1):9-16.
33. Tepel J, Schafer E. Endodontic hand instruments: cutting efficiency, instrumentation of curved canals, bending and torsional properties. Endod Dent Traumatol. 1997 Oct; 13 (5):201-10.
34. Tepel J, Schafer E, Hoppe W. Properties of endodontic hand instruments used in rotary motion. Part 1. Cutting efficiency. J Endod. 1995 Aug;21(8):418-21.
35. Teixeira FB, Souza-Filho FJ. Apical extrusion of debris and irrigants using two hand and three engine-driven instrumentation techniques. Int Endod J 2001;34:354-58.
36. Thomas Clauder, MA Baumann. Protaper NT system Dent Clin N Am (48) 87-111.
37. Thompson SA, Dummer PMH. Shaping ability of HERO 642 rotary nickel-titanium instruments in simulated root canals: Part 2. Int Endod J 2000 b;33:255-61.
38. Thompson SA, Dummer PM. Shaping ability of ProFile. 04 Taper Series 29 rotary nickel-titanium instruments in simulated root canals: Part I. Int Endod J 1997a;30:1-07.
39. Teresa Ponce de Leon Del Bello, Nancy Wang, James B. Roane, Crown-Down Tip Design and Shaping. Journal of endodontics 2003;29(8).
40. Yeung-Yi Hsu, Syngcuk Kim. The profile system Dent Clin N Am (48) 69-85.

INTRODUCTION

The ultimate aim of root canal therapy is to eliminate pathogenic microorganisms. This can be achieved by thorough cleaning and shaping and intracanal medication. Through the ages, various chemicals have been experimented with, to achieve the ideal sterilant, ranging from phenols to calcium hydroxide.

History

The historical origins of intracanal medicaments date back to very early times.

- Seribonius in AD 1045 wrote of using oils and wine in the mouth of a patient in pain. This was a crude attempt to achieve a topical anesthetic effect on a tooth to be extracted.
- Dental writings through the middle ages indicate the use of oil of cloves, a plant extract containing a high percentage of eugenol.
- In 1800 specific medicaments were recommended for endodontic treatment
- Beachwood creosate was mentioned in 1840 article which is still in use today.
- In 1884 Richmond advocated "knocking out the pulp" by whittling down orangewood to a small size, soaking the stick in phenol and tapping this into exposed pulp canal. Phenol was added to preserve and sterilize the contents of canal and to alleviate pain.

Ideal Requirements

- Effective germicide and fungicide
- Non-irritating to the periapical tissues.
- Stable in solution
- Should have antimicrobial effect for prolonged period
- Active in the presence of blood serum and protein derivatives
- It should have low surface tension
- It should not interface with repair of periapical tissues.
- It should not stain tooth structure
- It should not induce cell mediated immune response
- It should be capable of inactivation in a culture medium.

CLASSIFICATIONS

According to Grossman

1. Essential oils- Eugenol
2. Phenolic Compounds
   - Phenol
   - Para Chlorophenol
   - Camphorated Para Chlorophenol
   - Formocresol
   - Glutaraldehyde
   - Cresatin
3. Halogens
   - Sodium hypochlorite
   - Iodides
4. Quaternary Ammonium Compounds
   - 9 - amino acridine

According to DCNA

1. Phenolics
   - Eugenol
   - Camphorated Phenol

- Monochlorophenol (MCP)
- Camphorated Monopara Chlorophenol (CMCP)
- Meta cresylacetate (Cresatin)
- Cresol
- Creosote (Beechwood)
- Thymol

2. Aldehydes
   - Formo cresol
   - Glutaraldehyde
3. Halides
   - Sodium hypochlorite
   - Iodine - potassium iodide
4. Steroids
5. Calcium hydroxide
6. Antibiotics
7. Combinations

Mode of Action

Conventional antimicrobials attack cells in various ways. When used in high concentration they have a destructive effect on the bacteria so as to cause denaturation of cell proteins. Antimicrobial agents such as phenols, thymol, creosote, eugenol cause coagulation of proteins and subsequently, loss of cell metabolic function may result.

Detergents act as germicides by modifying and damaging the physical and chemical properties of the bacterial cell membrane. Iodine, Chlorine and heavy metals are strong enzyme inhibitors and therefore have a destructive effect on microbial cells.

INDIVIDUAL INTRACANAL MEDICAMENTS

Essential Oils

- Essential oils are weak disinfectants
- Eugenol is the chemical essence of oil of clove
- It is slightly more irritating than clove oil and is both antiseptic and anodyne
- Chemically soothing to vital tissues.

Phenol

- It is the oldest compound to prevent growth of microorganisms. It was introduced by Lord Lister in 1867.
- Also called carbolic acid
- It is white crystalline substance, and has a characteristic odor derived from coal tar
- Phenol is a protoplasm poison and produces necrosis of soft tissues by its ability to penetrate and disrupt the cell wall of bacteria and subsequently the protoplasm.
- Liquefied phenol consists of 9 parts of phenol and 1 part water
- This substance is highly effective in as low concentration as 1 to 2 percent

Phenol and its derivatives are powerful disinfectants which do not penetrate deeply because they precipitate albumin.

In clinical use the phenolic compounds are relatively ineffective as antiseptics.

Camphorated Phenol

Composition : 30 percent Phenol,
60 percent Camphor,
10 percent Ethyl alcohol

- It is the least toxic of the phenolic compounds
- It has excellent antimicrobial effect and also relieves pain
- Camphorating process aims at developing a less caustic medicament as a result of the slow release of phenol. Camphor serves as a vehicle and diluent.

MONOCHLOROPHENOL (MCP)

It is a derivative of phenol and has three isomer of which paramonochlorophenol is the most effective.

Monochlorophenol is a more effective antiseptic and is also more toxic than phenol.

CAMPHORATED PARAMONO CHLOROPHENOL (CMCP)

(Developed by Walkhoff 1891)

Composition: 35 percent Monochlorophenol
65 percent Camphor

- Its antimicrobial effeciency is good.
- But it is highly toxic to the tissues.
- It is used in the form of vapor forming intracanal medicaments. The vapors can pass through the apical foramen.

FORMOCRESOL (FIG. 13.1)

Developed by Buckley in 1906

Composition: 19 percent formaldehyde
35 percent Cresol
46 percent H_2O and glycerin.

Fig. 13.1: Formocresol

Fig. 13.2: Eugenol

It is a combination of formalin and cresol in the proportion of 1: 2

- Formocresol combines the protein coagulating effect of phenolic compounds with the alkylating effect of formaldehyde.
- The bactericidal effect of formocresol is good at levels as low as 2 percent.
- Its vapor forming effect is also good.
- It is a strong poison and causes widespread destruction of living tissue followed by a persistent inflammatory reaction.
- Studies have reported that formocresol treated tissue produced a cell mediated immune response.
- The formaldehyde in contact with tissue in the pulp and periapical tissues is transported to all parts of the body. Considering the outright toxic and tissue destructive effects and the mutagenic and carcinogenic potential, there is no clinical reason to use formocresol as an antimicrobial agent for endodontic treatment. These are better alternatives are better with significantly lower toxicity.

GLUTARALDEHYDE

- It is a colorless oil, slightly soluble in H_2O.
- Slightly acidic.
- It is a strong disinfectant and fixative.
- Used in concentration of 2 percent as intracanal medicament.
- Extent of toxicity is less compared to formaldehyde. Its molecular weight is high compared to formaldehyde. Hence, it does not penetrate into the periapical tissues.

CRESATIN

- Also known as metacresylacetate.
- It is a clear, stable, oily liquid of low volatility.
- It has both antiseptic and obtundant properties.
- Compared to formocresol or camphorated parachlorophenol, the antimicrobial effect of cresatin is less.
- Its effect on tissue range from mild to severe.

CREOSOTE

- It is a mixture of phenol and phenol derivatives.
- Beachwood creosote has long been used in endodontic therapy.
- There are several reports on severe tissue irritation and necrosis.

EUGENOL (FIG. 13.2)

- It is the chemical essence of oil of clove.
- It is related to phenol.
- It is both an antiseptic and an obtundant.
- It is slightly more irritating than oil of clove
- Studies have reported that eugenol inhibits intradental nerve impulses.
- A few reports of allergy to eugenol have been reported.

HEAVY METAL SALTS

- Salts of silver, copper and mercury are used as intracanal medicament.
- They coagulate proteins and act as enzyme inhibitors.

- They are toxic
- The mercury salts are rendered less effective by the tissue fluid proteins present in the root canal. Hence, they are not often used.

N2/RC2B

Introduced by Sargenti.

Composition

- Paraformaldehyde
- Phenylmercuric borate
- Eugenol
- Additional ingredients like lead, corticosteroids
- Antibiotics.

It is claimed to be both an intracanal medicament and a sealer.

N2 has a permanent disinfectant action and unusual antimicrobial properties. Its use has been denied by the Council on Dental Therapeutics of the American Dental association because of carcinogenicity.

The antibacterial effect of N2 is short-lived about-a week to days.

HALOGENS

It includes chlorine and iodine containing compounds.

Sodium Hypochlorite

- Hypochlorite was first used by Semmelweis in 1847 as a hand disinfectant.
- This initial use of potassium hypochlorite was substituted by sodium hypochlorite by Carrel and Dakin for wound disinfection.
- Mechanism of action: When hypochlorite contacts tissue proteins, nitrogen, formaldehyde and acetaldehyde are formed. The peptide links are broken up and this dissolves the proteins. During the process hydrogen in the amino groups (-HN-) is replaced by chlorine (-NCL-) thereby forming chloramine, which plays an important role in antimicrobial effectiveness.

Thus, necrotic tissue and pus are dissolved and the antimicrobial agent can better reach and clean the infected areas.

Temperature significantly improves the antimicrobial effect of sodium hypochloride.

Dakin suggested a 0.5 percent solution (Dakin's solution). At this concentration toxicity is low and it affects only necrotic tissue.

A 1 percent sodium hypochlorite solution however is more potent and provides an increased antimicrobial effect.

Higher concentration of NaOCl (2.5 and 5%) attack living tissue without contributing significantly to treatment (i.e. in antibiotic activity).

Bystrom and Sundquist have demonstrated that the rate of root canal disinfection was similar regardless of whether 0.5 or 5 percent concentration of NaOCl was used.

The activity of NaOCl is intense but of short duration. Hence, the compound should preferable be applied to the root canal every other day.

IODIDES

- Iodine has been used for many years and is known for its mild effect on living tissue.
- Iodine is highly reactive, combining with proteins in a loosely bound manner so its penetration is not impeded.
- Iodine potassium iodide which contains 2 percent I2, 4 percent KI and 94 percent distilled water has excellent antimicrobial activity and minimal toxicity and tissue irritating qualities.

CATIONIC DETERGENTS

- The quaternary ammonium compounds have low surface tension and a good cleansing effect.
- The antimicrobial effect of these compounds is not strong.
- Mechanism of action is as follows: the "Quats" are positively charged and the microorganisms are negatively charged. Thus, a surface active effect in which the compound clings to the microorganism and reverses the charges take place.
- These compounds may delay wound healing.
- These are used in the concentrations between 0.1 percent and 1 percent for root canal irrigation, but rarely as intracanal dressings.
- Salvizol is also a detergent suggested for irrigation during root canal instrumentation.

CALCIUM HYDROXIDE (FIG. 13.3)

- It has chelating effect.
- Salvizol causes some degree of tissue irritation.
- Hermann introduced Calcium hydroxide paste as an Intracanal medicament in 1920.

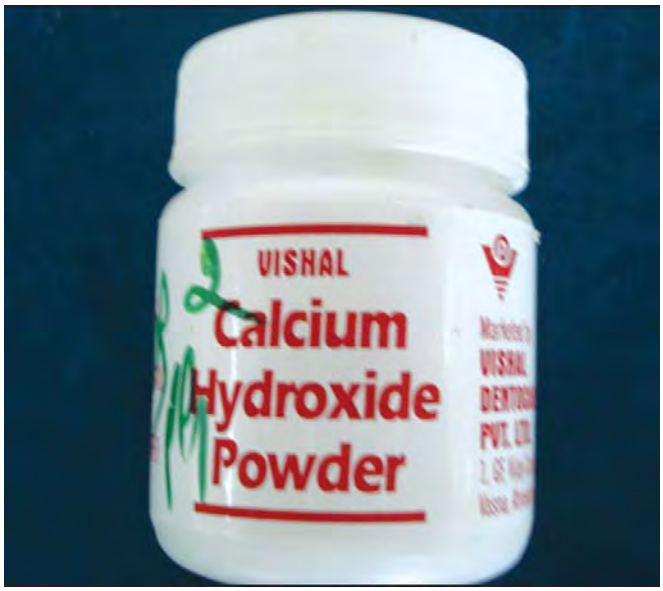


Fig. 13.3: Calcium hydroxide

- Calcium hydroxide paste for intracanal use is a thick suspension of $Ca(OH)_2$ powder in sterile water or saline.
- The high pH of calcium hydroxide paste is responsible for the destructive effect on bacterial cell membrane and protein structured. Few bacteria can survive at this pH of approximately 12.5.
- In addition to its antimicrobial qualities the paste may also aid directly or indirectly in the dissolution of necrotic pulp tissue. Tissues submerged in calcium hydroxide for a day is more easily dissolved with NaOCl than is untreated tissue.
- Bystrom et al showed that Calcium hydroxide paste effectively eliminated all microorganisms in infected root canal, when the dressing was maintained for 4 weeks.

ANTIBIOTICS AND STEROIDS

- Alone and in combination with other drugs, antibiotics are indicated in a small minority of cases when root canal infection persists despite other antiseptics.
- Ledermix paste or polyantibiotic paste (PBSC) are used.

LEDERMIX PASTE

Contains: 1 percent triamcinelone acetonide
3 percent dimethylchlortetracycline.

PBSC PASTE (POLY ANTIBIOTIC PASTE)

Contains: Penicillin G (10, 00,000 units)
Bacitracin (10,000 units)
Streptomycin sulphate
Sodium caprylate.

FREQUENCY OF MEDICATION

According to the general principle of root canal management, disinfectant dressings should preferably be renewed in a week and not longer than 2 weeks because dressings become diluted by periapical exudates and are decomposed by interaction with the microorganisms.

Traditionally, the mode of application was to use a short blunt absorbent point moistened with the medicament and placed into the canal, a cotton pledget, from which excess medicaments has been expressed is placed in the pulp chamber and the access cavity is sealed. In narrow canals a dry absorbent point is inserted and a cotton pledget moistened with the medicaments is placed against the absorbent point to moisten it. A dry cotton pledget is used to absorb the excess medicament and the cavity is sealed.

However, many endodontists prefer to place a medicated cotton pellet in the chamber from which excess medicament has been removed. They depend on the vaporization of the medicament in the pulp chamber for antibacterial action. They do not place an absorbent point in the root canal. The access cavity then sealed with a temporary restorative material.

ANTIMICROBIAL EFFECTIVENESS

The effectiveness of antimicrobials depends upon the direct contact of the agent with the virus, bacteria or fungus and in sufficient concentration. It is a limitation that the agent substance probably does not reach all areas where bacteria are sequestered.

Another significant concern is the duration of effectiveness of the medicaments in the pulp space. Recent research has shown that the antibacterial potency of phenolics drops off very quickly and becomes ineffective.

Also of concern is toxicity- anything that kills microbes also may destroy or depress host cells. Numerous in vitro and in vivo studies have examined these toxicity factors.

SUGGESTED READING

1. Athanassiadis B, Abbott PV, Walsh LJ. The use of calcium hydroxide, antibiotics and biocides as antimicrobial medicaments in endodontics. Aust Dent J 2007;52(1 Suppl):S64-82. Review.
2. Basrani B, A Ghanem, L Tjaderhane. Physical and chemical properties of Chlorhexidine and Calcium hydroxide-containing medications. J of Endod 2004;30(6):413-17.
3. Basrani B, Lemonie C. Chlorhexidine gluconate.Aust Endod J. 2005;31(2):48-52. Review.
4. Carson KR, G Goodell, S Mc- Clanahan. Comparison of the Antimicrobial Activity of Six Irrigants on Primary EndodonticPathogens. J of Endod 2005;31(6):471-73.
5. Estrela C, et al. Mechanism of Action of Sodium Hypochlorite. Braz Dent J 2002;13(2)113-17.
6. Estrela C, F Pimenta, I Ito, L Bammann. Antimicrobial Evaluation of Calcium hydroxide in Infected Dentinal Tubules. J of Endod 1999;25(6):416-18.
7. Estrela C, L Bammann, F Pimenta, J Pecora. Control of microorganisms in vitro by calcium hydroxide pastes. Int. Endod J 2001;34:341-45.
8. Ferrari PH, S Cai, A Bombana. Effect of endodontic procedures on enterococci, enteric bacteria and yeasts in primary endodontic infections. Int. Endod J 2005;38: 372-80.
9. Gomes B, et al. In vitro antimicrobial activity of several concentrations of sodium hypochlorite and chlorhexidine gluconate in the elimination of Eterococcus faecalis. Int Endod J 2001;34:424-28.
10. Gomes B, et al. Microbiological examination of infected root canals. Oral Microbiol Immunol 2004;19(2)71-76.
11. Gomes BP, Vianna ME, Sena NT, Zaia AA, Ferraz CC, de Souza Filho FJ. In vitro evaluation of the antimicrobial activity of calcium hydroxide combined with chlorhexidine gel used as intracanal medicament. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006 Oct;102(4):544-50. Epub 2006;4.
12. Haenni S, et al. Chemical and Antimicrobial properties of calcium hydroxide mixed irrigating solutions. Int. Endod. J 2003;36:100-105.
13. Ingle JI, LK Bakland. Endodontics. Fifth Edition, 2002,BC Decker Inc. Hamilton·London 67-74.
14. Kalaskar R, Damle SG, Tiku A. Nonsurgical treatment of periapical lesions using intracanal calcium hydroxide medicament—a report of 2 cases. Quintessence Int. 2007; 38(5):e279-84.
15. Krithikadatta J, Indira R, Dorothykalyani AL. Disinfection of dentinal tubules with 2 percent chlorhexidine, 2 percent metronidazole, bioactive glass when compared with calcium hydroxide as intracanal medicaments. J Endod 2007;33(12):1473-76.
16. Lin NY, Gao XJ. [A short-term clinical study of one-visit endodontic treatment for infected root canals] Zhonghua Kou Qiang Yi Xue Za Zhi. 2006;41(9):525-8. Chinese.
17. Lin S, Levin L, Weiss EI, Peled M, Fuss Z. In vitro antibacterial efficacy of a new chlorhexidine slow-release device. Quintessence Int. 2006;37(5):391-94.
18. Nandini S, Velmurugan N, Kandaswamy D. Removal efficiency of calcium hydroxide intracanal medicament with two calcium chelators: volumetric analysis using spiral CT, an in vitro study. J Endod. 2006;32(11): 1097-1101.
19. Oliveira LD, Leão MV, Carvalho CA, Camargo CH, Valera MC, Jorge AO, Unterkircher CS. In vitro effects of calcium hydroxide and polymyxin B on endotoxins in root canals. J Dent. 2005 Feb;33(2):107-14. Epub 2004;10.
20. Oncag O, Cogulu D, Uzel A, Sorkun K. Efficacy of propolis as an intracanal medicament against Enterococcus faecalis. Gen Dent. 2006;54(5):319-22.
21. Pallotta RC, Ribeiro MS, de Lima Machado ME. Determination of the minimum inhibitory concentration of four medicaments used as intracanal medication. Aust Endod J 2007;33(3):107-11.
22. Radcliff CE, et al. Antimicrobial activity of varying concentrations of sodium hypochlorite on the endodontic microorganismsActinomyces israeli, A. Naeslundi, Candida albicans and E faecalis. Int. Endod. J 2004;37: 438-46.
23. Silveira AM, Lopes HP, Siqueira JF Jr, Macedo SB, Consolaro A. Periradicular repair after two-visit endodontic treatment using two different intracanal medications compared to single-visit endodontic treatment. Braz Dent J. 2007;18(4):299-304.
24. Siqueira J, et al. Chemomechanical Reduction of the Bacterial Population in the Root Canal after Instrumentation and Irrigation with 1 percent, 2.5 percent, and 5.25 percent Sodium Hypochlorite. J of Endod 2000;26(6):331-34.
25. Siqueira J, H Lopes. Mechanisms of antimicrobial activity of calcium hydroxide: a critical review. Int Endod J 1999;32:361-69.
26. Siqueira J, M Uzeda. Intracanal Medicaments: Evaluation of the Antibacterial Effects of Chlorhexidine, Metronidazole and Calcium Hydroxide Associated with Three Vehicles. J of Endod 1997;23(3):167-69.
27. Soares JA, Leonardo MR, da Silva LA, Tanomaru Filho M, Ito IY. Effect of rotary instrumentation and of the association of calcium hydroxide and chlorhexidine on the antisepsis of the root canal system in dogs. Braz Oral Res. 2006;20(2):120-26.
28. Wang CS, Debelian GJ, Teixeira FB. Effect of intracanal medicament on the sealing ability of root canals filled with Resilon. J Endod. 2006;32(6):532-6. Epub 2006 Apr 4.
29. Zehnder M, Lehnert B, Schönenberger K, Waltimo T. [Irrigants and intracanal medicaments in endodontics] Schweiz Monatsschr Zahnmed. 2003;113(7):756-63. Review. German.

14 Root Canal Sealers

Definition

- Sealers are binding agents, used to fill the gap between root canal wall and obturating material.
- They also fills up the irregularities, discrepancies, lateral canals and accessory canals.

Ideal Requirements of a Sealer

1. It should provide an excellent seal apically and laterally.
2. Should produce adequate adhesion when it sets.
3. Should be radiopaque.
4. Should be non-staining.
5. Should be dimensionally stable.
6. Should be easily mixed and introduced in the root canal.
7. Should be insoluble in tissue fluids.
8. Should be bactericidal and non-irritating
9. Should be slow setting.
10. Should be resorbable when extruded beyond apex.

Properties of sealers	*Objectives*
1. Provide fluid tight seal	Core material itself does not provide good obturation. Sealer fills the gap between the core material and canal wall and also flows into the accessory canals.
2. Radio-opacity	Most of the sealers are radio-opaque. This allows visualization in the radiograph and assessment of seal obtained.
3. Should have adequate setting time	Sealers should have adequate setting time to coat the canal and gutta-percha. It should allow for sufficient time to complete the obturation procedure.

Contd...

Contd...

Properties of sealers	*Objectives*
4. Should not be soluble in fluids	Most of the sealers are insoluble in oral fluids. But they disintegrate over a period of time when they come in contact with oral fluids.
5. Should be Non-irritating	It should be biocompatible. If it comes in contact with vital periapical tissue. It should not cause irritation.
6. Should be bacteriostatic	Most of the sealers have antibacterial property to prevent the growth of the bacteria which were left behind in the canal after cleaning and shaping procedures.
7. Should not shrink during setting	Majority of the sealers will not shrink during setting. If they shrink, this will leads to microleakage and eventually, failure of the endodontic treatment.
8. Should not stain the tooth surface	Most of the present sealer components will not cause discoloration except silver containing sealers which cause discoloration at the coronal portion due to leaching of the silver. Nowadays silver is not used as a component in sealers.
9. Should be easily removed from the canal	For post space preparation and retreatment, sealers should be removed easily either by mechanical method or by solvent.

Functions

1. Anti-microbial agent
2. Binding agent
3. Filler: Used to fill gaps between cone and walls
4. Lubricant: When used with obturating material
5. Radiopaque: Since it discloses the presence of accessory canals

Classification

According to composition [messing]			
A. Eugenol *i. Silver containing*	*ii. Silver Free*	*B. Non-eugenol*	*C. Medicated*
1. Rickert's formula Kerr's Sealer (1931) 2. Procosol Radiopaque silver cement (Grossman-1936)	1. Procosol Non-staining G cement (Grossman-1958) 2. Grossman's sealer (Grossman-1974) 3. Tubliseal (Kerr-1961) 4. Wach's Paste (Wach 1925-55)	1. DIAKET (1951) 2. AH 26 (1957) 3. AH plus 4. Hydron 5. Chloropercha 6. Eucapercha 7. Nogenol 8. Endofil 9. Glass ionomer 10. Polycarboxylate 11. Calcium phosphate cements 12. Cyanoacrylates	1. DIAKET-A 2. N_2 (1970) 3. Endomethasone 4. Spad 5. Iodoform paste 6. Riebler's paste 7. Mynol cement 8. Ca $(OH)_2$ paste (Lanes, 1962) 9. Ca $(OH)_2$ (Frank, 1962) [Biocalex]

According to Grossman

- Zinc oxide eugenol cements
- Calcium hydroxide cements
- Paraformaldehyde based
- Pastes

According to Harty

- Zinc oxide eugenol based cements
- Resin based cements
  - AH 26,
  - AH Plus
  - Diaket,
  - Hydron
- Gutta-percha based
- Dentin adhesive material - GIC
- Cyanoacrylates
- Medicated
  - Seal apex
  - Biocalex
  - Para formaldehyde

The most common zinc oxide eugenol cements are Rickert's sealer, Grossman's sealer, Wach's paste, and Tubliseal.

The original zinc oxide-eugenol cement, developed by Rickert's, was the standard for the profession for many years. However, the silver, added for radiopacity, causes discoloration of the teeth.

In 1958, Grossman recommended non-staining zinc oxide eugenol cement as a substitute for Rickert's formula. It has become the standard by which other cements are measured because it reasonably meets most of Grossman's requirements for a cement.

1. Kerr Root Canal Sealer/Rickert's Formula

Composition

Powder:

Zinc oxide	→	34-41.2%
Precipitated silver	→	25-30.0%
Oleo resins	→	30-16%
Thymol iodide	→	11-12%

Liquid:

Oil of cloves	→	78-80%
Canal balsam	→	20-22%

Advantages

- Excellent lubricating properties.
- It allows a working time of more than 30 minutes when mixed in 1:1 ratio.
- Germicidal action and biocompatibility.
- Greater bulk than any sealer and hence fills voids, accessory canals and irregularities present lateral to gutta-percha cones.
- Prostaglandin inhibition property (Zinc Eugenolate).

Disadvantage

- Stains dentin to dark gray color.

Indications

This is indicated in warm gutta-percha technique where lateral canals are present.

Manipulation

One drop of liquid is mixed with one pellet of powder. Granular appearance remains even after spatulation is completed because of precipitated silver. It completely sets and is inert within 15-30 minutes.

2. ***Procosol radiopaque silver cement***
3. ***Procosol non-staining root canal cement (Grossman-1958):*** Grossman's formula was proposed in 1936 with the purpose of developing a sealer that afforded more working time.
4. ***Grossman's sealer (Grossman-1974)***

Power

Zinc oxide	-	42%
Stabelite resin	-	27%
Bismuth subcarbonate	-	15%
Barium sulfate	-	15%
Sodium borate (anhydrous)	-	1%

Liquid

Eugenol	-	100%

Setting time: 2 hours at 37ºC.

In the root canal, Grossman sealer sets within 10-30 minutes due to the presence of moisture in the dentin.

Factors influencing the setting time:

- Quality of zinc oxide
- pH of resin
- Technique of mixing to its proper consistency.
- Amount of humidity
- Temperature and dryness of mixing slab and spatula.

Manipulation

Sterile glass slab and spatula are taken. Not more than 3 drops of liquid should be used at a time, because excessive time and effort would be required to spatulate a large amount. Small increments of powder are added to liquid and mixed to a creamy consistency.

Spatulation time - 1 minute/drop

The cement will not harden for 6-8 hrs if left on the glass slab.

The mixed batch of cement can therefore be used for several hours. If it thickens, spatulation will break up any crystals formed and will restore the mix to proper consistency. In the canal, because of moisture in the dentinal tubules, it begins to set in half an hour.

Tests for Proper Consistency

Drop Test

The mass of cement is gathered onto the spatula and held edgewise. The cement should not drop off the spatula's edge for 10-12 sec. A root canal instrument can also be used for this test. After a no. 25 file is rotated in the gathered mass of cement, it is withdrawn and held in a vertical position. Correctly mixed cement should remain with very little movement in the blade of the instrument (5-10 sec). If a tear drop forms, the mix is too thin and more powder should be added.

String Test

After touching the mass of cement with its flat surface, the spatula is raised slowly from the glass slab. The cement should string out at least one inch without breaking.

Properties

1. It has plasticity and slow setting time
2. It has good sealing potential
3. Zn eugenolate is decomposed by water through continuous loss of eugenol which makes the compound unstable.

Setting Time

- Cement hardens in 2 hrs at 37°C
- Manipulation is same as Zinc oxide-eugenol cement
- It should be of smooth creamy consistency
- A correctly mixed cement should remain on the instrument for 15-20 seconds.
- If tear drop forms, then the mix is thin.
- If there is extrusion of cement, may cause inflammatory reaction.

Advantages of ZnOE Cement (Fig. 14.1)

- Ease of manipulation
- Slight dimensional change

Fig. 14.1: Zinc oxide eugenol sealer

- Radiopaque
- Minimal Staining
- Ample working time
- This sealer if extruded apically gets absorbed
- Grossman's sealer is soluble in chloroform, carbon tetrachloride, xylol and ether.
- The sealer is easily removed from the glass slab and spatula with alcohol or solvent.
- It presents a minimal level of irritation and high level of antimicrobial activity.
- Plasticity and slow setting time due to the presence of sodium borate anhydrate.

Disadvantages

1. Resin is of coarse particle size and unless the material is spatulated vigorously during mixing, an increased piece of resin may lodge on the walls of the canal and prevent the root-canal filling from sealing at correct level.
2. Zinc eugenolate can be decomposed of water through a continuous loss of eugenol making zinc oxide eugenol a weak, unstable material.
3. Toxicity studies have shown that a small amount when extruded may first cause an inflammatory reaction; nevertheless it is well tolerated by the periapical tissues.
4. When a periapical lesion is present, a transient toxic effect of the medicament is permissible to delay rate of healing. Often the excess is removed from the periapical tissues by phagocytosis.

NON-EUGENOL SEALERS

Kloroperka N-Sealer

Formula suggested by Nyborg and Tullin in 1965

Composition

Powder

- Canada balsam 19.6%
- Resin 11.8%
- Gutta-percha 19.6%
- Zinc oxide 49%

Liquid

- Chloroform

Disadvantage: Greater degree of leakage.

Chloropercha

Mixture of gutta-percha and chloroform

Disadvantage: Excessive shrinkage

Indications

- Used in perforations, curved canals or canals with ledge.
- If used with well fitted primary cone chlorpercha can fill accessory canals.

AH-26

- Epoxy resin sealer recommended by Schroeder 1954.
- It consists of yellow powder and viscous resin liquid.

Properties

- Good adhesive property.
- Antibacterial.
- Low toxicity and well tolerated by periapical tissue.
- Sufficient working time.

Setting Time

Exceptionally slow setting (36-48 hrs)

Powder		*Liquid*
Bismuth oxide	60 %	Bisphenyl
Hexamethylene Tetramine	25 %	Diglycidyl ether
Silver oxide	10 %	
Titanium oxide	5 %	
Paraformaldehyde		

Fig. 14.2: AH plus

Disadvantages

1. Formaldehyde release (Carcinogenic)
2. Paresthesia may occur in overfilled canals (1-2 yrs)

AH PLUS (FIG. 14.2)

AH Plus is a two component paste root canal sealer used for permanent sealing based on epoxide-amine resins. This easy to mix sealer conforms closely to the walls of the prepared root canal, and provides outstanding long-term dimensional stability with minimal shrinkage upon setting, tissue compatibility, radiopacity, color stability and ease of removal. Handling too is quicker and easier. Ideal for use with Thermafil.

Epoxy Paste	*Amine Paste*
Epoxy Resin	Amines
Calcium tungstate	Calcium tungstate
Zirconium oxide	Zirconium oxide
Silica	Silica
Iron oxide	Silicone oil

Advantages

1. Higher radiopacity
2. Better manipulation
3. No release of formaldehyde

Properties	*AH-26*	*AH-Plus*
System	Powder: Liquid 2:1	Paste A : Paste B
Working time	6-8 hrs	1- 14 hrs
Setting time	36-48 hrs	9-15 hrs
Composition	Silver containing	Silver free
Formaldehyde	Released	No
Reaction with H_2O_2	Forms bubbles	No reaction
Uses	Obturating material without core	Only sealer

AH Plus Jet

AH Plus is now available in a double barrel syringe, the AH Plus Jet Mixing Syringe. This dispenser ensures that the paste is mixed in an ideal ratio and means that the sealer can be applied directly and precisely into root canals. This makes the process of applying sealer easier and faster.

Advantages

- Controlled, homogenous mixing of both pastes, giving an ideal consistency.
- Clean and direct application into root canals.
- Increased efficiency, saving time.

DIAKET

Introduced in Europe by Sheuffle in 1952.

It is a Polyvinyl resin, a reinforced chelate formed between Zinc oxide and diketone. It hardens rapidly.

Setting time is 6-8 min on slab.

Properties

- Resistance to absorption.
- More tensile strength.
- Inflammatory reaction in overfilled canals. (Mortification of cementum and alveolar bone)
- Frequently used to cement endosseous implant.

Diaket A

- Chemically is similar to diaket, but contains disinfectant Hexachlorophene.
- It is one of the medicated sealers that do not contain paraformaldehyde.

HYDRON (INJECTABLE CEMENT)

- Introduced by Withtelle and Lim in 1960.
- It is a polymer of hydroxy ethyl methacrylate (HEMA)
- Rapid setting hydrophilic, plastic material used as a root canal filling material without the use of a cone.

Properties

- Available as injectable root canal filling material.
- Working time is 6-8 mins.
- Absorbs water and swells when it comes in contact with moisture.
- Low radiopacity.
- Retreatment is difficult.

ENDOFILL

Injectable silicone resin sealant used either with a core material (Gutta-percha) or as a sole sealant and filling material in the canal with a pressure syringe.

Properties

Good adaptation to tooth structure and fills the accessory canals.

Setting time is 8-9 mins.

Advantages	*Disadvantages*
• Ease of preparation	• Can't use in presence of H_2O_2
• Adjustable working time	• Canal must be dry
	• Shrinkage upon setting
• Non-resorbable material	• Used within 20 mins for better results

N2/RC2B

It was introduced by Sargenti and Ritcher in 1961.

Composition

- Zinc oxide Eugenol
- Paraformaldehyde,
- Lead tetroxide
- Steroids

According to animal studies N2 is very toxic.
Two different types of N2 sealers were available:

a. N2 - Normal - Used for root filling
b. N2 - Apical - Antiseptic medication of canal
Recently N2 Universal has been introduced.

Biocompatibility

- In case of over filling, paresthesia is observed.
- Blood lead level is increased after the insertion.

Effectiveness of Sealer

N2 apical seal is better compared to Procosol, Nogenol, Tubliseal and Diaket.

ENDOMETHASONE

- Zinc oxide based sealer with cortisone and paraformaldehyde
- Corticosteroid masks inflammatory reaction.

Composition

Powder

• Zinc oxide	100 g
• Bismuth subnitrate	100 g
• Dexamethasone	0.019 g
• Hydrocortisone	1.6 g
• Thymol iodide	25 g
• Paraformaldehyde	2.20 g

NOGENOL

This was developed to overcome the irritating quality of eugenol. The product is an outgrowth of a non-eugenol periodontal pack.

Composition

- Zinc sulphate
- Barium sulphate
- Vegetable oil.

Catalyst

- Hydrogenated rosin
- Methyl abeitate
- Lauric acid
- Chlorothymol
- Salicylic acid

Advantages

- Nogenol is a less irritating sealer
- The sealer expands on setting and may improve its sealing efficacy with time.

CALCIUM HYDROXIDE CEMENTS

- Calcium hydroxide is used in endodontics as a root canal filling material.
- An intracanal medicament or as a sealant with core material
- pH - 11-12.5

Examples:

- Sealapex - (Kerr Company)
- CRCS - Calcobiotic Root canal sealer
- Life
- Apexit
- Vitapex
- Biocalex
- SPAD

CRCS (Hygienic Corporation 1982)

Calcibiotic Root Canal Sealer was the first calcium hydroxide based sealer.

Powder

Zinc oxide
- Hydrogenated rosin
- Barium sulfate
- Eucalyptol
- Calcium hydroxide
- Bismuth subcarbonate

Liquid

- Eugenol

Zinc oxide eugenol and eucalyptol are added to Calcium hydroxide for its osteogenic effect. It takes 3 days to set completely.

SEAL APEX

It is a calcium hydroxide containing sealer delivered as paste and paste systems in collapsible tubes.

Composition

Base

- Zinc oxide 6.5%
- Calcium hydroxide—25.0%
- Butyl benzene
- Sulfonamide
- Zinc stearate

Catalyst

- Barium sulfate—18.6%
- Titanium dioxide—51%
- Proprietary resin
- Isobutyl salicylate
- Aerocil R 972.

In 100 percent humidity, Seal apex takes 3 weeks to set. In a dry atmosphere it never sets. It expands on setting. A negligible amount of dissolution occurs when extruded from the periapex. The dissolution is probably due to water sorption thus eventually breaking the apical seal. The fluid sorption characteristics may be due to its porosity that allows marked ingress of water. It is a biologically active sealer intended to promote periapical healing.

Holland reported the ability of Sealapex to induce apical closure by cementum in histological studies.

Life

It is a calcium hydroxide liner and pulp capping material similar in formulation to Sealapex. It has also been suggested as a sealer.

Apexit

Liechtenstein introduced calcium hydroxide sealer called Apexit.

Composition

Base

Calcium hydroxide	31.9%
Zinc oxide	5.5%
Calcium oxide	5.6%
Silicon dioxide	8.1%
Zinc stearate	2.3%
Hydrogenised colophony	31.5%
Tricalcium phosphate	4.1%
Poly dimethyl siloxane	2.5%

Activator

Trimethyl hexanedioldisalicylate	25.0%
Bismuth carbonate basic	18.2%
Bismuth oxide	18.2%
Silicon dioxide	15.0%
1,3 Butanediol di salicylates	11.4%
Hydrogenised colophony	5.4%
Tricalcium phosphate	5.0%
Zinc stearate	

VITAPEX

This sealer was first introduced in Japan. Its components are iodoform and silicone oil. One week following deposition in rats, calcium ions of Vitapex labeled calcium hydroxide, were found throughout the skeletal system. This attests to the dissolution and uptake of this material. No evidence is given about the sealing or osteogenic capabilities of Vitapex.

SPAD

- One visit non-irritant radiopaque sealer
- It is "Resorcinol formaldehyde resin"

Powder		*Liquid (Clear)*
ZnO	72.9 g	Formaldehyde
Barium sulfate	13 g	Glycerine
Titanium dioxide	6.3 g	
Paraformaldehyde	4.7 g	Liquid
Hydrocortisone acetate	2 g	Glycerine
Ca $(OH)_2$	0.44 g	Resorcinol
		HCl

- The essential reaction to form the resin occurs between resorcinol and formaldehyde.
- Setting time 24 hrs (unreacted formaldehyde gas released).

Indications

- Pulpotomies in both dentition
- Acute endodontic infection
- Teeth with periapical lesions.

BIOCALYX

Introduced by Bernard (1952).

Powder

- Heavy Calcium oxide,
- Zn oxide

Liquid

- Glycol
- Water

The powder and liquid are mixed to a paste. Acts as - Root canal medicament and Root canal filler. After being sealed in the canal It expands six times its original volume.

Setting Mechanism

Calcium oxide and water react within the tooth to form the calcium hydroxide which ionizes to release (OH)- ions. Decomposes necrotic pulp tissue to form water and carbon dioxide. The water combines with residual calcium oxide leading to further calcium hydroxide formation while carbon dioxide reacts with calcium hydroxide to form calcium carbonate which is deposited in the root canal walls. The contents of the canals are subjected to chemical incineration with sterilization occurring by the action of (OH)- ions and sealing of the canal by decomposition of Calcium carbonate.

Efficacy of sealing the root canal achieved with Biocalyx is a controversy.

IODOFORM

Described by WALKHOFF (1928)

- Commercially known as Kri-paste.
- It is a resorbable paste used alone or in combination with core materials.
- It is intentionally placed beyond the apex to stimulate inflammatory reaction and thus repair.

Composition

Powder: Iodoform
Liquid: Parachlorophenol
- Camphor
- Menthol

Disadvantages

1. Periapical irritation
2. Discoloration

NEWER SEALERS

1. Endoflas.
2. Ketac-Endo Glass Ionomer Root Canal Sealer
3. Roeko-seal
4. Gutta-flow Sealer
5. Endo-rez sealer
6. Epiphany sealer
7. Apatite root canal sealer
8. Root canal sealers containing -tetracalcium dicalcium phosphate and 1 percent chondroitin sulfate.

ENDOFLAS (FIG. 14.3)

It is a zinc oxide based medicated sealer.

Composition

Powder: Zinc oxide
Iodoform
Calcium hydroxide
Barium sulfate
Liquid: Eugenol
Parachlorophenol

- Relatively biocompatible
- Setting time is approximately 30-45 minutes

Fig. 14.3: Endoflas

- Severe cytotoxicity was observed along with coagulation necrosis that is attributed to the presence of iodoform and parachlorophenol.

KETAC-ENDO GLASS IONOMER ROOT CANAL SEALER

Composition

Powder

- Fluoro-aluminosilicate glass.
- Calcium volframate
- Silicic acid

Liquid

- Polycarbonic acid and Maleic acid copolymers
- Tartaric acid
- Water.

– Sealing root canals.
– Provides molecular bonding to dentin, strengthens roots in danger of fracturing, reinforces the tooth, and reduces risk of microleakage.
– Provides adequate working time for root canal procedures.
– Optimal flow characteristics allow easy root canal placement.
– Aplicap capsule offers consistent, accurate mix and easy, hygienic dispensing.
– High radiopacity.
– Prevents penetration of bacteria to reduce risk of secondary infection.

Disadvantages: Removal is difficult.

ROEKO SEAL

Roeko seal is a silicone-based root canal sealer with poly dimethyl siloxane as the main composition.

This sealer has excellent flow properties. The extremely low film thickness of only 5 μm allows the sealer to flow into tiny crevices and dentine tubules.

The solubility of this sealer is very low.

Dimensional stability is good. It does not shrink but actually expands slightly (0.2%).

It is extremely biocompatible.

GUTTA FLOW SEALER

Gutta Flow unites gutta-percha and sealer in a product and has outstanding material properties.

Composition

1. Polydimethylsiloxane
2. Silicone oil
3. Paraffin oil
4. Platinum catalyst
5. Zirconium dioxide
6. Nano-silver
7. Gutta-percha powder

The material has excellent flow characteristics, which make an optimal distribution in the root channel as well as the racking possible of lateral channels and Isthmus. Gutta Flow can be removed during Retreatments problem-free.

ENDO REZ SEALER

Endo REZ is a two part, dual cure set endodontic sealer and filler based on UDMA resin—the same type of resins used today as orthopedic bone cements so biocompatibility is assured. Endo REZ® displays the same radiopacity as Gutta-percha, thus, simplifying radiographic interpretation. Endo REZ is hydrophilic and has unique apical delivery system. These two features combine to improve sealing ability, eliminate air entrapment leading to air displaced obturation system.

EPIPHANY SEALER

This is the part of the Resilon-epiphany obturation system.

Composition of Epiphany Sealer

- UDMA, PEGDMA, EBPADMA, BISGMA RESIN
- Silane treated bariumborosilicate glasses
- Barium sulphate, Silica, Calcium hydroxide, Bismuth oxychloride with amines, peroxide
- Photo initiator, stabilizer, pigments

With this filling system, the primer bonds dentin wall, while the sealer bonds to both the primer and the filling points forming a monoblock. This configuration eliminates shrinkage and subsequent gaps; it also significantly decreases leakage, strengthens the root, and increases resistance to root fracture.

APATITE ROOT CANAL SEALER

One of the recently introduced Sealers

Powder	*Liquid*
Tricalcium phosphate Hydroxylapatite Iodoform Bismuth Subcarbonate	Polyacrylic acid Distilled water

Available as three types:

1. *Type I:* Vital Pulpectomy
2. *Type II:* 30 percent idoform - used in infected canals
3. In between cases: 5 percent iodoform.

Indications

1. Treatment of accidental perforation.
2. Retrograde root canal filling after Apicoectomy.

Advantages	*Disadvantages*
• Biocompatible • Osteogenic potential • Low tissue toxicity	• Sets quickly • Low radiopacity • Low wetting ability

NEWLY DEVELOPED CALCIUM PHOSPHATE TYPE SEALERS

a. Tetracalcium phosphate (TeCP)
b. Dicalcium Phosphate Dihydrate (DCPD)
c. A modified MCII veins and Buffer solution (TDM)
d. TDM - S - Buffer solution + 2.5 percent chondroitin sulfate.

TDM - S

Powder	*Liquid*
Tetracalcium phosphate Dibasic calcium phosphate	Dibasic sodium phosphate Citric acid • Distilled water

- Studies have shown excellent biocompatibility.
- No periapical inflammatory reaction.
- Chondroitin and other ingredients said to promote wound healing.

BIOSEAL: PCS

- This is a hydroxyapatite-based root canal sealer.
- Commonly used for vertical condensation.

Sealing ability of this new-hydroxyapatite containing endodontic sealer using lateral condensation and thermatic condensation of gutta-percha in vitro has been tested (JOE, Vol. 22; No. 4: April 96).

HYDROX

- Is assumed to influence the apical healing.
- It may affect the sealing ability of the cement because of its composite structure. Additives did not effect the sealing ability.

APPLICATION OF A SEALER

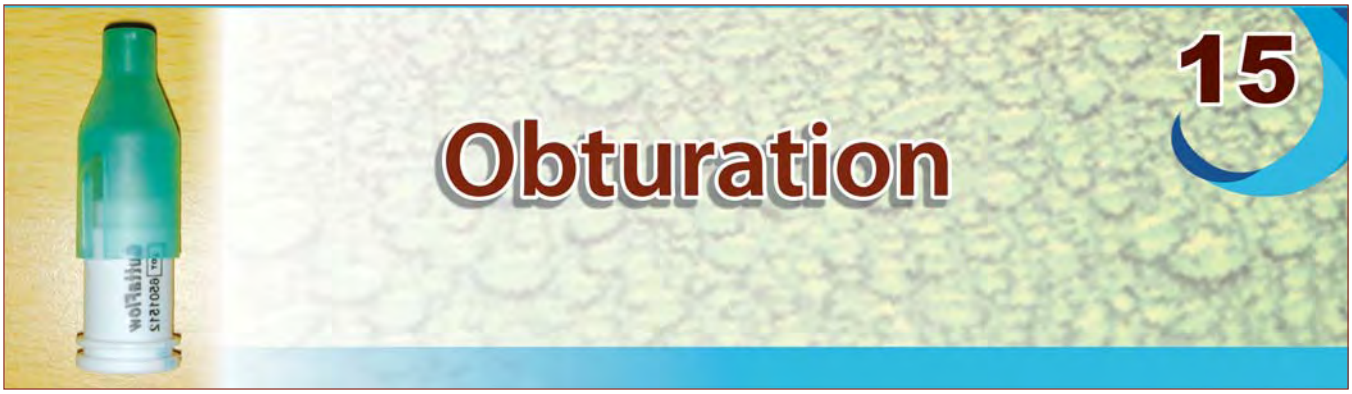
- Lentulospiral
- Reamer/File
- Master cone with sealer
- Ultrasonic.

SUGGESTED READING

1. Almeida JF, Gomes BP, Ferraz CC, Souza-Filho FJ, Zaia AA. Filling of artificial lateral canals and microleakage and flow of five endodontic sealers. Int Endod J 2007; 40(9):692-99.
2. Barbizam JV, Souza M, Cecchin D, Dabbel J. Effectiveness of a silicon-based root canal sealer for filling of simulated lateral canals. Braz Dent J 2007;18(1):20-23.
3. Bouillaguet S, Wataha JC, Tay FR, Brackett MG, Lockwood PE. Initial in vitro biological response to contemporary endodontic sealers. J Endod 2006;32(10):989-92.
4. Baldissara P, Zicari F, Valandro LF, Scotti R. Effect of root canal treatments on quartz fiber posts bonding to root dentin. J Endod 2006;32(10):985-88.
5. Bodrumlu E, Semiz M. Antibacterial activity of a new endodontic sealer against Enterococcus faecalis. J Can Dent Assoc 2006;72(7):637.

6. Brekalo I, Pezelj-Ribaric S, Abram M, Ahel V. Effect of root canal sealers on mouse peritoneal macrophage functions. Folia Microbiol (Praha) 2007;52(1):95-98.
7. Baksi Akdeniz BG, Eyuboglu TF, Sen BH, Erdilek N. The effect of three different sealers on the radiopacity of root fillings in simulated canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103(1):138-41.
8. Batista RF, Hidalgo MM, Hernandes L, Consolaro A, Velloso TR, Cuman RK, Caparroz-Assef SM, Bersani-Amado CA. Microscopic analysis of subcutaneous reactions to endodontic sealer implants in rats. J Biomed Mater Res A 2007;81(1):171-77.
9. Biggs SG, Knowles KI, Ibarrola JL, Pashley DH. An in vitro assessment of the sealing ability of resilon/epiphany using fluid filtration. J Endod 2006;32(8):759-61.
10. Canoglu H, Tekcicek MU, Cehreli ZC. Comparison of conventional, rotary, and ultrasonic preparation, different final irrigation regimens, and 2 sealers in primary molar root canal therapy. Pediatr Dent 2006;28(6):518-23.
11. Cobankara FK, Orucoglu H, Sengun A, Belli S. The quantitative evaluation of apical sealing of four endodontic sealers.
12. Caicedo R, Alongi DJ, Sarkar NK. Treatment-dependent calcium diffusion from two sealers through radicular dentine. Gen Dent 2006;54(3):178-81.
13. Davis ST, O'Connell BC. The effect of two root canal sealers on the retentive strength of glass fibre endodontic posts. J Oral Rehabil. 2007;34(6):468-73.
14. De-Deus G, Coutinho-Filho T, Reis C, Murad C, Paciornik S. Polymicrobial leakage of four root canal sealers at two different thicknesses. J Endod 2006;32(10):998-1001.
15. Da Silva Neto UX, de Moraes IG, Westphalen VP, Menezes R, Carneiro E, Fariniuk LF. Leakage of 4 resin-based root-canal sealers used with a single-cone technique. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104(2): e53-7.
16. Eldeniz AU, Mustafa K, Orstavik D, Dahl JE. Cytotoxicity of new resin-, calcium hydroxide- and silicone-based root canal sealers on fibroblasts derived from human gingiva and L929 cell lines. Int Endod J 2007;40(5):329-37.
17. Eldeniz AU, Erdemir A, Kurtoglu F, Esener T. Evaluation of pH and calcium ion release of Acroseal sealer in comparison with Apexit and Sealapex sealers. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103(3): e86-91.
18. Economides N, Panagiotis B, Kolokouris I, Gogos C, Kokorikos I. Comparative study of the sealing ability of a polydimethylsiloxane-based root canal sealer. Braz Dent J 2005;16(2):145-48.
19. Eldeniz AU, Erdemir A, Hadimli HH, Belli S, Erganis O. Assessment of antibacterial activity of EndoREZ. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;102(1): 119-26.
20. Gu HJ, Liu LM, Xu Q, Ou-Yang Y, Ling JQ. [Evaluation of sealing ability of three kinds endodontic materials as root canal sealers] Hua Xi Kou Qiang Yi Xue Za Zhi 2007;25(3):257-59. Chinese.
21. Gernhardt CR, Kruger T, Bekes K, Schaller HG. Apical sealing ability of 2 epoxy resin-based sealers used with root canal obturation techniques based on warm gutta-percha compared to cold lateral condensation. Quintessence Int 2007;38(3):229-34.
22. Ghoddusi J, Rohani A, Rashed T, Ghaziani P, Akbari M. An evaluation of microbial leakage after using MTAD as a final irrigation. J Endod 2007;33(2):173-76.
23. Gambarini G, Testarelli L, Pongione G, Gerosa R, Gagliani M. Radiographic and rheological properties of a new endodontic sealer. Aust Endod J 2006;32(1):31-34
24. Ho YC, Huang FM, Chang YC. Cytotoxicity of formaldehyde on human osteoblastic cells is related to intracellular glutathione levels. J Biomed Mater Res B Appl Biomater 2007;83(2):340-44.
25. Hiraishi N, Loushine RJ, Vano M, Chieffi N, Weller RN, Ferrari M, Pashley DH, Tay FR. Is an oxygen inhibited layer required for bonding of resin-coated gutta-percha to a methacrylate-based root canal sealer? J Endod 2006; 32(5):429-33.
26. Huang FM, Chang YC. Induction of heme oxygenase-1 expression by root canal sealers in human gingival fibroblasts is augmented by oxidative stress. J Biomed Mater Res B Appl Biomater 2007;80(2):499-504.
27. Juhasz A, Verdes E, Tokes L, Kobor A, Dobo-Nagy C. The influence of root canal shape on the sealing ability of two root canal sealers. Int Endod J 2006;39(4):282-86.
28. Kosti E, Lambrianidis T, Economides N, Neofitou C. Ex vivo study of the efficacy of H-files and rotary Ni-Ti instruments to remove gutta-percha and four types of sealer. Int Endod J 2006;39(1):48-54.
29. Kontakiotis EG, Tzanetakis GN, Loizides AL. A comparative study of contact angles of four different root canal sealers. J Endod 2007;33(3):299-302.
30. Lee DH, Lim BS, Lee YK, Yang HC. Mechanisms of root canal sealers cytotoxicity on osteoblastic cell line MC3T3-E1. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 104(5):717-21.
31. Lee DH, Lim BS, Lee YK, Kim NR, Yang HC. Inhibitory effects of root canal sealers on the expression of inducible nitric oxide synthase in lipopolysaccharide-stimulated murine macrophage cells. J Biomed Mater Res B Appl Biomater 2007;83(1):91-96.
32. Lee YY, Hung SL, Pai SF, Lee YH, Yang SF. Eugenol suppressed the expression of lipopolysaccharide-induced proinflammatory mediators in human macrophages. J Endod 2007;33(6):698-702.
33. Lacey S, Pitt Ford TR, Yuan XF, Sherriff M, Watson T. The effect of temperature on viscosity of root canal sealers. Int Endod J 2006;39(11):860-33.
34. Merdad K, Pascon AE, Kulkarni G, Santerre P, Friedman S. Short-term cytotoxicity assessment of components of the epiphany resin-percha obturating system by indirect and direct contact millipore filter assays. J Endod 2007; 33(1):24-27.
35. Melegari KK, Botero TM, Holland GR. Prostaglandin E production and viability of cells cultured in contact with freshly mixed endodontic materials. Int Endod J 2006;39(5):357-62.

36. Nielsen BA, Beeler WJ, Vy C, Baumgartner JC. Setting times of Resilon and other sealers in aerobic and anaerobic environments.
37. Pameijer CH, Zmener O. Current status of methacrylate-based sealers and obturation techniques. Pract Proced Aesthet Dent 2006; 18(10):674, 676. No abstract available.
38. Patel DV, Sherriff M, Ford TR, Watson TF, Mannocci F. The penetration of RealSeal primer and Tubliseal into root canal dentinal tubules: a confocal microscopic study. Int Endod J 2007;40(1):67-71.
39. Partovi M, Al-Havvaz AH, Soleimani B. In vitro computer analysis of crown discolouration from commonly used endodontic sealers. Aust Endod J 2006;32(3):116-19.
40. Sly MM, Moore BK, Platt JA, Brown CE. Push-out bond strength of a new endodontic obturation system (Resilon/Epiphany). J Endod 2007;33(2):160-62.
41. Susini G, About I, Tran-Hung L, Camps J. Cytotoxicity of Epiphany and Resilon with a root model. Int Endod J 2006;39(12):940-44.
42. Sousa CJ, Montes CR, Pascon EA, Loyola AM, Versiani MA. Comparison of the intraosseous biocompatibility of AH Plus, EndoREZ, and Epiphany root canal sealers. J Endod 2006;32(7):656-62.
43. Schirrmeister JF, Kielbassa AM. Coronal leakage of calcium phosphate-based root canal sealers compared with usual sealers. Schweiz Monatsschr Zahnmed 2006;116(3): 224-28.
44. Tunga U, Bodrumlu E. Assessment of the sealing ability of a new root canal obturation material. J Endod 2006;32(9):876-78.
45. Tabrizizadeh M, Mohammadi Z. In vitro evaluation of antibacterial activities of root canal sealers. J Clin Dent 2005;16(4):114-6.
46. Tay FR, Pashley DH, Loushine RJ, Doyle MD, Gillespie WT, Weller RN, King NM. Ultrastructure of smear layer-covered intraradicular dentin after irrigation with BioPure MTAD. J Endod 2006;32(3):218-21.
47. Tay FR, Hiraishi N, Pashley DH, Loushine RJ, Weller RN, Gillespie WT, Doyle MD. Bondability of Resilon to a methacrylate-based root canal sealer. J Endod 2006; 32(2):133-37.
48. Winik R, Araki AT, Negrao JA, Bello-Silva MS, Lage-Marques JL. Sealer penetration and marginal permeability after apicoectomy varying retrocavity preparation and retrofilling material. Braz Dent J 2006;17(4):323-27.
49. Yucel AC, Guler E, Guler AU, Ertas E. Bacterial penetration after obturation with four different root canal sealers. J Endod 2006;32(9):890-93.
50. Zafalon EJ, Versiani MA, de Souza CJ, Moura CC, Dechichi P. In vivo comparison of the biocompatibility of two root canal sealers implanted into the subcutaneous connective tissue of rats. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103(5):e88-94.



Gutta-percha has been the filling material of choice in endodontics since its introduction by Bowman in 1867. It comes in three different types: alpha, beta and amorphous forms. Although other materials and techniques have been used to overcome some of the disadvantages inherent in gutta-percha, none has come close to meeting the eleven requirements for an ideal root canal filling material established by Dr Louis Grossman. These requirements have been attempted to be met with systems delivering injectable thermosoftened gutta-percha.

Objectives of Obturation

The prime biologic consideration is the elimination of the continuum between the oral cavity and the periodontium wherein the root canal system is the biologic vector responsible for leakage of toxins into the attachment apparatus. By effectively removing this vector, healing of pathologically altered periradicular tissues can be facilitated.

Prerequisites for Obturation

Thorough biomechanical debridement and disinfection of the root canal system is essential prior to obturation.The adjunctive use of endosonics, the effective use of irrigants and chelating agents and better technical understanding of the mechanics of cleaning and shaping have enabled the achievement of this goal. The canal must be free of inflammatory infiltrate and be shaped in a manner consistent with the dictates of a three dimensional obturation (tapering funnel). It is essential that the tooth be asymptomatic and no evidence of swelling noted.

DIFFERENT TECHNIQUES OF ROOT CANAL OBTURATION

A. *Cold lateral condensation method*
B. *Warm vertical condensation method:*
   1. Touch 'n' heat
   2. System B
   3. EndoTwinn
C. *Thermocompactors:*
   1. New McSpadden nickel titanium thermo-compacter
   2. Maillefer gutta condenser
   3. Zipperer
D. *Canal Finder plugger (automated plugger)*
E. *Thermoplasticized gutta-percha techniques:*
   1. Ultrafil
   2. Obtura system
   3. Pac 1600
   4. Inject-R-FILL
   5. Calamus flow obturation unit
   6. Microseal system
   7. Trifecta and successFil
   8. Soft core obturation
F. *Ultrasonic plasticizing:*
   1. Cavitron with Pr-30 insert
   2. ENAC
G. *Other systems:*
   1. Resilon
   2. Gutta flow
   3. Endo-Rez
   4. Active GP system
   5. Dentin chip apical filling

1. COLD LATERAL CONDENSATION

Selection of the Master Cone

Drying the Canal

While preparations are being made to cement the filling point, an absorbent paper point should be placed in the canal to absorb moisture or blood that might accumulate.

Larger paper points should be used first followed by smaller paper points until full length is achieved.

Placement of the Sealer

Mixing: A sterile slab and spatula are used for mixing. The cement is mixed according to the manufacturer's directions. The cement should be creamy in consistency and should string out at least an inch when the spatula is lifted from the mix.

Sealer can be placed in abundance to ensure through canal wall.

Placement of the Master Point

The premeasured primary point is now coated with cement and slowly moved to full working length. The sealer acts as a lubricant.

Obturation with Lateral Compaction (Figs 15.1 to 15.4)

When the fit of the cemented master cone is verified, the butt end should be removed with a hot instrument or scissors to allow room for visualization and the spreader that is to follow.

The premeasured spreader is then introduced into the canal alongside the primary point, and with a rotary vertical motion is slowly moved apically to full penetration, marked on the shaft with a silicone stop.

The spreader is then removed with the same reciprocating motion and is immediately followed by the first auxiliary point inserted to the full depth of the space left by the spreader.

Obturation is considered complete when the spreader can no longer penetrate the filling mass beyond the cervical line.

At this time the protruding points are severed at the orifice of the canal with a hot instrument.

Vertical compaction with a large plugger will then ensure the tightest possible compression of the gutta-percha mass and provide a more effective seal against coronal leakage.

Advantages

- Less technique sensitive, easy to manipulate.
- No additional cost.

Disadvantages

- Time consuming.
- More cones are required.
- Canal irregularities are difficult to fill.
- Chances of voids are more.

Procedure

Fig. 15.1: Cone selection

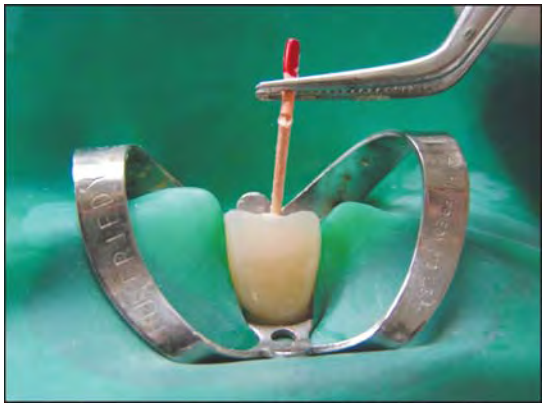


Fig. 15.2A: Fitting of master cone

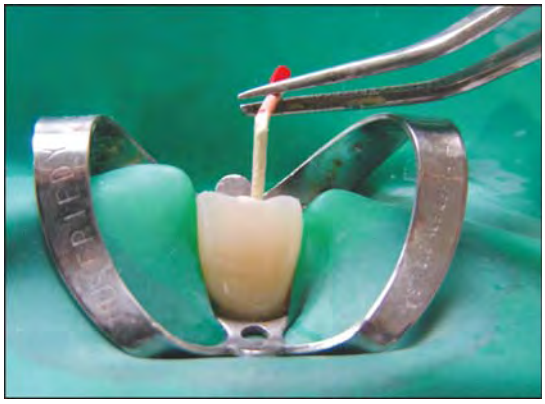


Fig. 15.2B: Placement of master cone

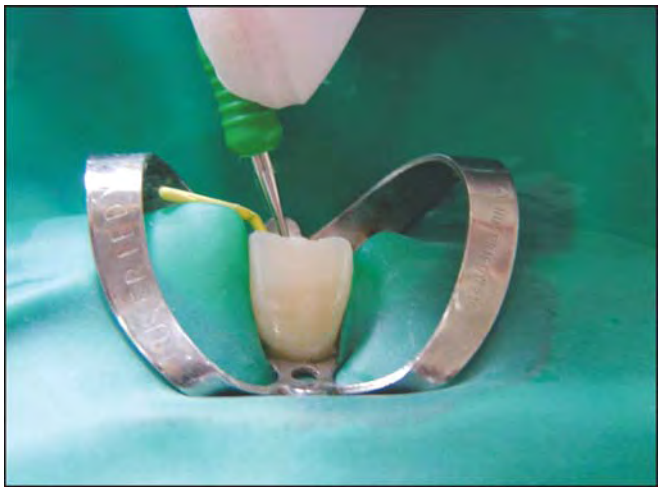


Fig. 15.3A: Spreader placement

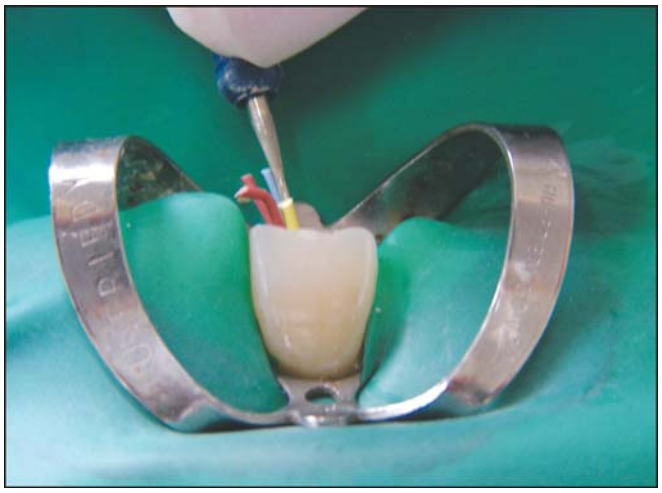


Fig. 15.3B: Spreader(35 no) creating space by applying pressure on master cone

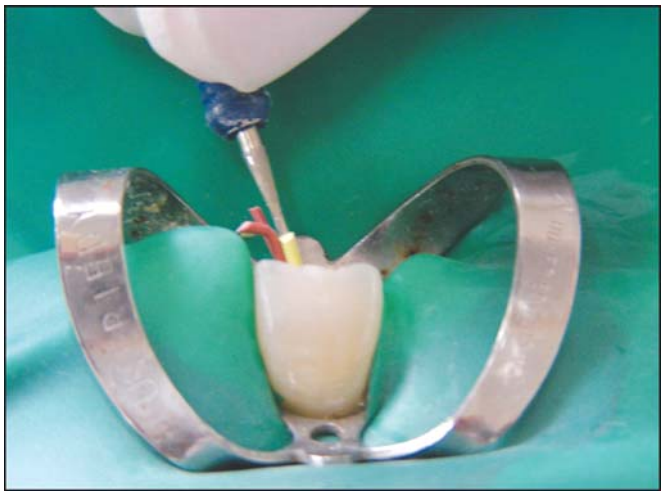


Fig. 15.4: Thirty number spreader

2. WARM VERTICAL CONDENSATION METHOD (FIGS 15.5A TO F)

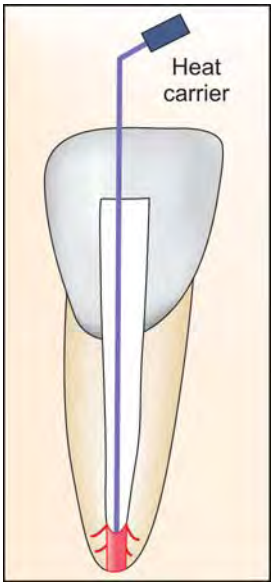


Fig. 15.5A: Heat carrier at apical third

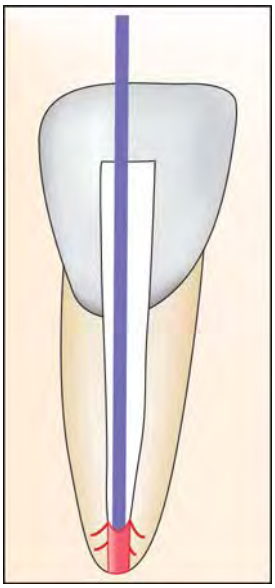


Fig. 15.5B: Plugger at apical third

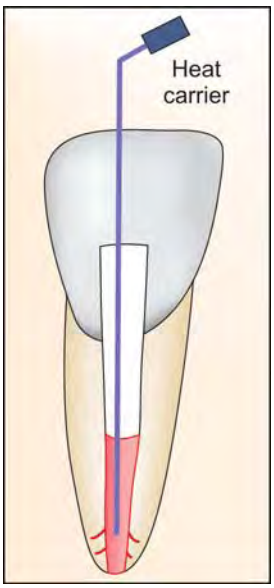


Fig. 15.5C: Heat carrier at middle third

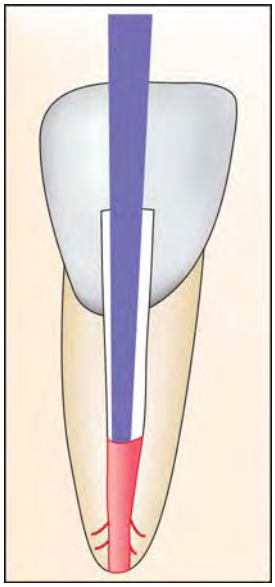


Fig. 15.5D: Plugger at middle third

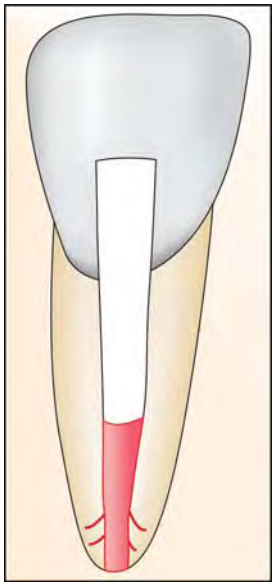


Fig. 15.5E: Canal obturated till middle third

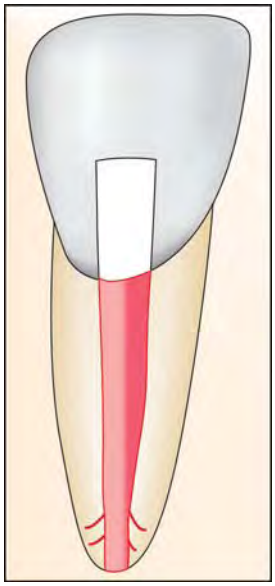


Fig. 15.5F: Obturated canal

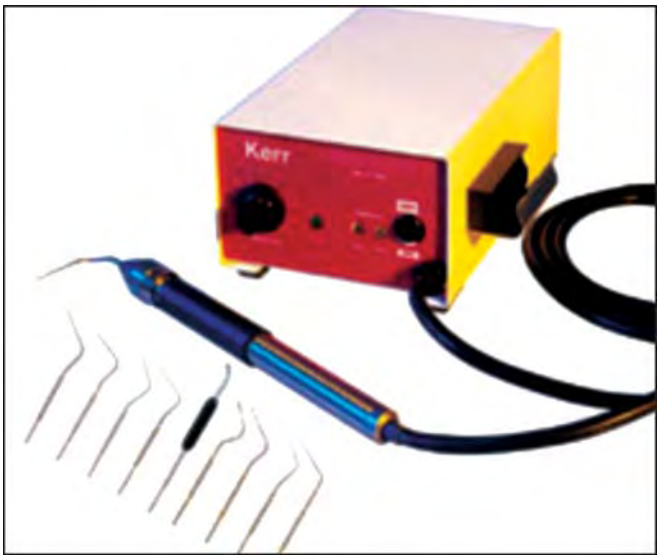


Fig. 15.6: Touch-n-heat

- Touch 'n' heat (Fig. 15.6)
- System B
- Endo Twinn

Touch 'n' Heat

The Touch 'n' heat unit is used with the Schilder's technique. The Touch 'n' heat 2004 is an electronic device, especially developed for the warm vertical compaction of gutta-percha.

Battery/AC models are available. It exhibits the same thermal properties as the original heat carrier used by Schilder in 1967 but has the advantage of generating heat automatically at the top of the instrument. The instrument is capable of providing a range of high temperatures instantly, ranging from 0 to 70°C. The device may also be used for pulp testing/bleaching by changing the tips and adjusting the heat level.

Procedure

The softened warm gutta-percha can be readily compacted apically into the irregularities of the root canal system.

The objective of this technique is to continuously and progressively carry a wave of warm gutta-percha along the length of the master cone starting coronally and ending apically.

Schilder's pluggers are selected and prefitted for coronal 1/3rd length (wide) and middle and apical 1/3rd length (narrow).

Down Packing

1. Prepared canal walls are first coated with sealer.
2. The selected master cone is a nonstandard gutta percha point with the apical tip cut off.
3. It is fitted to achieve apical tug-back at about 1 mm from the working length. (If the canal diameter is wider than the first point a second point is fitted.)
4. Gutta-percha protruding from the canal orifice is removed with a hot instrument.
5. The widest plugger is now used to compact the gutta-percha into the canal using 2-3 mm vertical strokes.
6. A series of overlapping strokes are used if the canal is wider than the plugger.
7. The heat transfer instrument, heated to cherry red, is again plunged into the mass of gutta-percha to a depth of 3-4 mm and quickly withdrawn (This high temperature ensures that a mass of gutta-percha is removed with the carrier.)
8. The appropriate prefit plugger is then used as already described.
9. This 3 dimensional adaptation and apical and lateral movement of gutta-percha is termed as "wave of condensation".
10. It is rarely necessary to compact closer than 5 mm from the working length. A smaller prefit plugger can be placed progressively deeper into the preparation thus producing a "2nd wave of condensation".
11. This procedure is done for about 4 to 5 times depending on the length of the canal. Repeat by carrying heat carries 4-5 mm from apex and condense with prefit condensers.

This cycle is completed by a sustained firm apical pressure held for a few seconds till the clinician feels that the thermosoftened mass has cooled.

Precautions

- There should be a continuous tapering canal preparation whose diameter is narrowest apically.
- Master cone should be fitted correctly.
- Temperature of Touch 'n' heat instrument should not exceed 45°C.
- Heated pluggers should not be placed closer than 4 to 5 m of canal terminus.

Back Packing Phase

The most effective and efficient back packing technique is using Obtura II gutta-percha gun.

The smallest 23 gauge needle is attached to the Obtura II gutta-percha gun until it comes in contact with the previously packed gutta-percha apically. The hot tip will ensure homogeneity during procedure. The Obtura gun is held firmly and slowly by squeezing the trigger and injecting a controlled 4 to 5 mm segment of uniformly thermosoftened gutta-percha against the previously packed apical third. If this is performed properly the clinician feels the gun back out of the canal easily. The smallest prefit plugger is used to condense the gutta-percha. Through a series of gutta-percha injections and condensations, the root canal is completely obturated. A confirmatory radiograph is taken.

Advantages

- Fills accessory canals
- Homogenous filling.

Disadvantages

- Voids (inadequate control of the depth of insertion of the filler)
- Small plugger is ineffective
- Plugger binding apically may split root.

SYSTEM B (FIG. 15.7)

Analytic technology has introduced the System B heat source model 100. This instrument has a digital temperature display and a variable resistance control that allows the user to attain a desired temperature.

System B is also based on the Schilder technique. These heat carriers are designed as pluggers that concentrate the heat at the tip of the carrier. The tip of the pluggers can be heated to 200°C; this softens the gutta-percha in ½ second.

A wave of heat (250-300°C) is produced as the plugger is forced through the already fitted cone and is used to drive the gutta-percha into the canal.

As the plugger approaches the apex, the heat button is released and apical pressure is maintained with the plugger for 10 seconds. To take up the shrinkage that occurs on cooling.

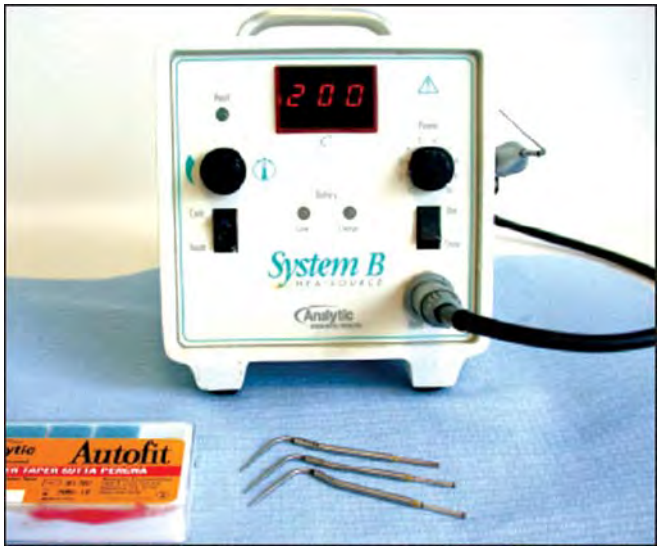


Fig. 15.7: System B

The heat button is pushed again while maintaining pressure. A wave of heat is produced (300°C in 5 seconds) that immediately separates the plugger from apical mass of gutta-percha. Thus, it can be rapidly withdrawn. The canal is then backfilled with Obtura.

Advantages

- Proper adaptation to walls.
- Elimination of voids
- Flow in the accessory and lateral canals

Disadvantages

- Breakage
- Kinking of spreaders

Silver GK, et al in 1999 conducted a study on "Comparison of two vertical condensation obturation techniques - Touch 'n' heat and system B".

They concluded that:

- System B may produce an acceptable obturation and produces less heat than Touch 'n' heat.
- Obturation by this method was faster.

ENDOTWINN (FIG. 15.8)

The EndoTwinn is an advanced instrument available for heating and compacting gutta-percha and other thermoplastic filling materials. It is single button controlled with advanced automatic temperature regulation which provides the required heat. Vibration can be applied for better compaction during entire obturation process.

Fig. 15.8: EndoTwinn

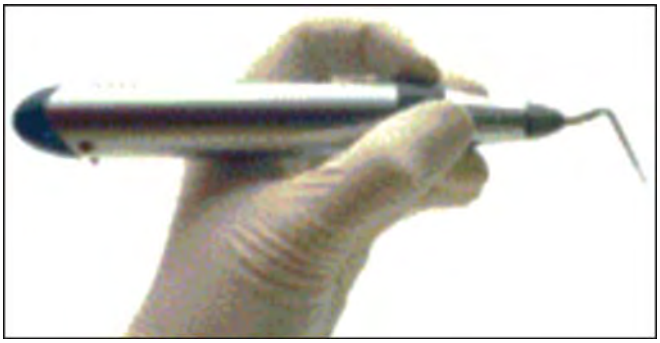


Fig. 15.9: EndoTwinn handpiece

The EndoTwinn system consists of a rechargeable cordless handpiece, a charging cradle, and a wall adapter.

Handpiece (Fig. 15.9)

The EndoTwinn is cordless with an ergonomic design and a easy to use.

Tip Plugger (Fig. 15.10)

A variation of tips is available for compacting, softening and cutting gutta-percha points. The EndoTwinn can be used with different types of autoclavable pluggers.

PC-series: Standard pluggers with 0.5 mm diameter and a range type F, FM, ML and L

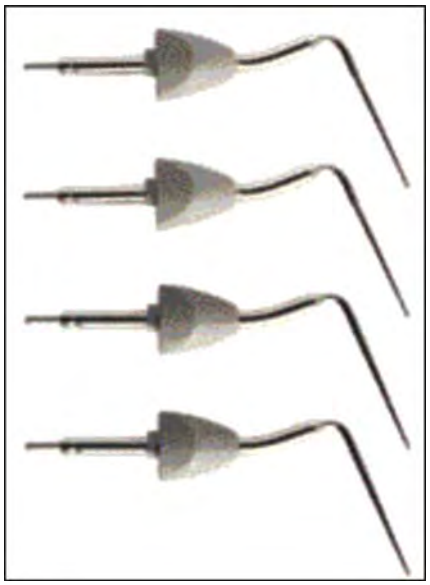


Fig. 15.10: Tip pluggers

Fig. 15.11: Tip spreaders

PD-series: The dimensions and the range is the same, but these tips are UltraSoft. The needle of the tip can be easily pre-bend before entering the root canal.

Tip Spreader (Fig. 15.11)

For use in warm lateral condensation technique this spreader tip (SB.340)is perfectly suited. The tip is operated at approximately 200 degrees in order to soften the gutta-percha. In combination with the vibration, gutta-percha will be compacted in the root canal. This way space will be created to place the next gutta percha cone. Similarly up to 30 percent more gutta-percha cones can be placed.

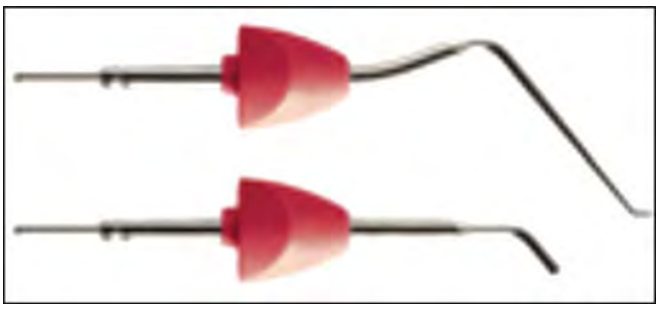


Fig. 15.12: Tip spoons

Tip Spoon (Fig. 15.12)

The spoon is a special tip with a cutting edge (SP.01) or a round edge (SP.49). This is suited for cutting plastic obturator handles within two seconds. The temperature of the tip is approximately 400 degrees. This tip is perfect for making a clean cut within a split second. So it is much easier and time-saving compared to other devices.

THERMOCOMPACTORS

In this technique friction between gutta-percha and the rotating "Reverse File" generates heat to soften the gutta-percha and force it apically. Thermo-compactors available have different designs which determine their properties.

1. New McSpadden nickel titanium thermocompacter
2. Maillefer gutta condenser
3. Zipperer

1. MCSPADDEN COMPACTOR (FIG. 15.13)

A new concept of heat softening gutta-percha was introduced by McSpadden in 1979 using the McSpadden compactor.

It resembles a reverse H-file which fits into a latch type handpiece, rotates at 8,000-20,000 rpm and generates frictional heat that softens gutta-percha and forces the material apically and laterally. As canal is filled, the compactor is forced out coronally.

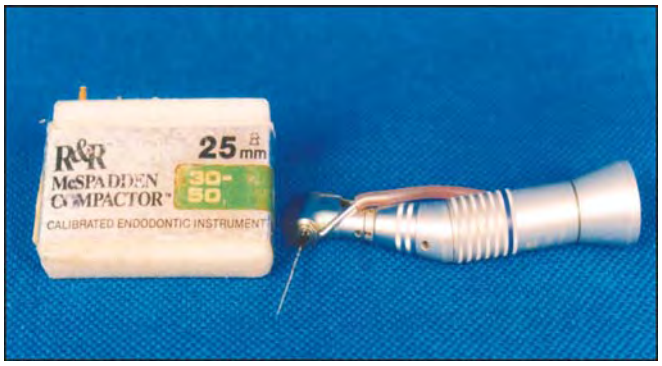


Fig. 15.13: McSpadden compactor

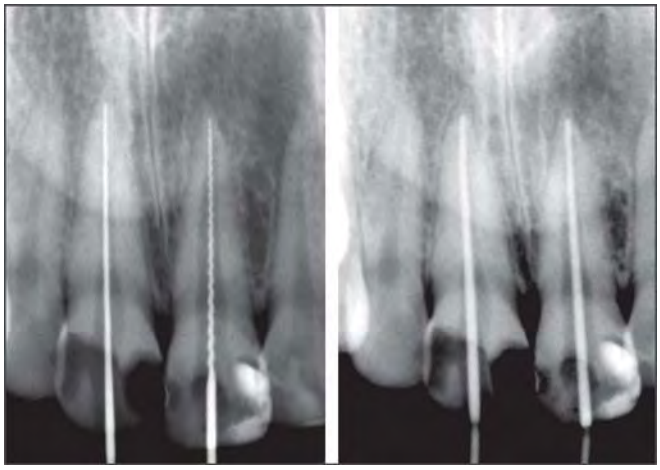
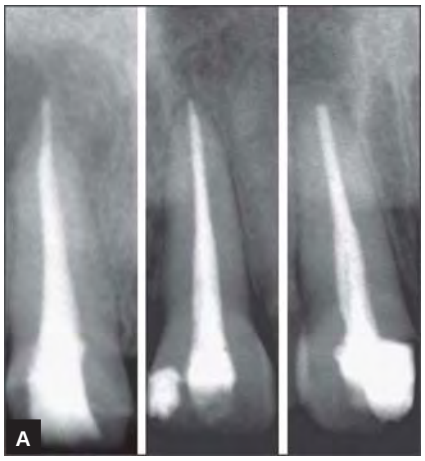
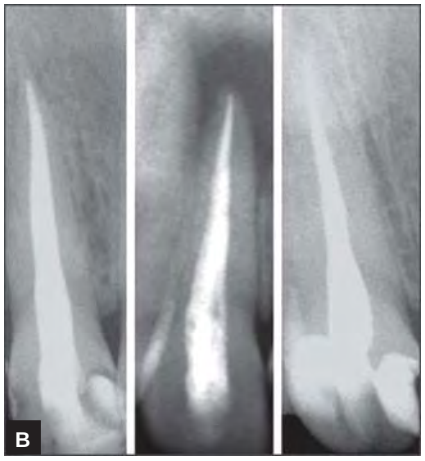


Fig. 15.14: Working length and master cone radiograph





Figs 15.15A and B: Post-obturation radiographs

Disadvantages of this technique are:

1. Fragility of the instruments – Prone to fracture. Hence cannot be used in curved canals.
2. Overfilling of the canals.
3. Difficulty in mastering technique
4. Overheating.
5. Resorption and ankylosis.

To overcome these disadvantages, different shapes and forms evolved McSpadden in the meantime modified the original design and introduced the NT condensers. They are supplied as an engine driven/ hand powered Ni-Ti instruments with following features.

- Increased number of compacting blades.
- Shallower grooves.
- Decreased sharpness.
- Made of NiTi for flexibility .

Procedure (Figs 15.14 and 15.15)

- Place primary gutta-percha cone in root canal.
- Select the appropriate size condenser, coat it with gutta percha (heat softened) gutta-percha I (α) or gutta-percha II (β).
- The condenser is then spun in the canal at 1000-4000 rpm which flings the gutta-percha laterally and vertically.
- The speed is controlled by NT matic handpiece.

2. MAILLEFER GUTTA CONDENSER

Maillefer modified the hedstrom type instrument as gutta condenser.

- It has less number of compacting blades.
- Increased sharpness.
- Deeper grooves.

Used: For back filling of canals already filled at apical third by either

a. Warm vertical compaction.
b. Sectional compaction.
c. Cold lateral compaction.

3. ZIPPER THERMOCOMPACTOR/ ENGINE PLUGGER

- This thermocompactor resemble an inverted K-file.
- Increased number of flutes
- Used for backfilling canals already filled at apical third
- In hybrid technique (Tagger).

Automated Plugger

The Canal Finder plugger is a stepwise flexible plugger shaped like a telescope. It is used in a Canal Finder handpiece which delivers a rapid vertical stroke varied between 0.3 and 1.0 mm.

Procedure

Sealer placement with the plugger
↓
Master cone placement
↓
Insertion of vertically vibrating plugger
↓
The edges of the plugger blades latches the gutta-percha
↓
Vertical and lateral compaction of gutta-percha.
↓
Addition of accessory gutta-percha points each time the plugger is used for compaction

This method has some discrepancies and is not commonly followed.

Use of this technique does not warm and plasticize the gutta-percha.

THERMOPLASTICIZED GUTTA-PERCHA TECHNIQUES

Injection Techniques

Ultrafil (Fig. 15.16)

Presented in 1984 by Dr Michanowicz and Czontokowsky.

Because of concern over high temperature generated, new thermoplasticized, low temperature (70°C) gutta-percha was developed along with a slightly different delivery system.

Fig. 15.16: Ultrafil System

Here gutta-percha comes prepacked in cannules with attached 22 gauge needle. The material is -phase which softens at a temperature of approx 158° to 194°F (70-90°C) in a special heating unit for 15 min. These warmed cannules are placed is a special sterilizable syringe for delivery to root canal.

Ultrafil is available in three types of cannules containing different viscosities of gutta-percha

1. Regular Set, White (excellent flowability, setting time: 30 min).
2. FirmSet, Blue (excellent flow ability, setting time: 4 min).
3. Endoset, Green (medium flow ability, setting time: 2 min).

Obtura System (Fig. 15.17)

Original obtura was produced by Unitek, but the instrument (called Guttagun) and the technique did not take hold as the company anticipated. Several other companies made slight alterations which lead to evolution of Obtura II.

Gutta-percha is available in pellets (β phase) that are inserted into heat delivery system, which looks like a caulking device. With an increased demand for this technique, variations in the consistency of gutta-percha are available. These variations are designed to improve flow and to regulate viscosity.

Fig. 15.17: Obtura System

1. *Regular flow:* Homogenized formulation with superior flow characteristics.
2. *Easy flow:* Maintains its smooth flow at low temperatures. It has long working time, so favors the management of complex cases.
   - Where extensive compaction is needed
   - Curved canals
   - Inexperienced clinician

Gutta-percha is heated approximately to 185-200°C but the temperature of gutta-percha extruding from needle tip will be in the range of 62 to 65°C.

The silver needle designed to deliver softened gutta-percha is available in 20 gauge (60 size file) and 23 gauge (40 size file).

Method of Use

Sealer and compaction is necessary for this method.

- Sealer serves its usual role of filling microscopic interface between dentin and gutta-percha as well as lubricant.
- Compaction becomes necessary to close spaces and gaps to compensate for shrinkage as gutta-percha cools.
  1. Prefit a cold plugger to 4-6 mm from the apical termination.
  2. Prefit the applicator tip/needle to the same depth to ensure that it doesn't bind against canal walls.
  3. Place a thin coat of slow setting sealer on canal walls. Carefully to prevent its movement beyond the confines of canal apically.
  4. With needle in proper position, inject softened gutta-percha passively avoiding apical pressure into apical 4-5 mm. In 2-5 seconds it fills apical segment and begins to lift the needle out of the tooth.
  5. Vertically condense material with a push to the mass using a plugger.
  6. Back fill the remainder of canal.

Advantages

1. Results in movement of gutta-percha and sealer in to dentinal tubules.
2. Adaptation of injected gutta-percha to canal walls has been shown to be better than lateral compaction.

Disadvantages

1. Potential for extrusion of gutta-percha and sealer beyond apical foramen.
2. Possibility of heat damage to periodontium.

PAC-160 (Precision Apical Control at 160°C)

In late 1981, Schoeffel designed and built a prototype delivering system to operate indefinitely and accurately at 160°C. This new and safer syringe facilitates clinical application of thermoplastic injection moulding technique, using standard gutta-percha. It exactly resembles the device used by Yee et al for experimental studies and is called PAC-160 gutta-percha.

Flexible silver needles of different sizes (18, 20, and 25) are used to inject gutta percha which averages less than 20 sec and it takes around 2 min to get hardened which is adequate time for manual condensation.

Inject-R-Fill - Back Filling Technique (Fig. 15.18)

Another method of back filling has been developed by Roane at university of Oklahoma and is marketed as "Inject-R-fill".

Inject-R-fill, a miniature sized metal tube containing conventional gutta-percha and plunger, simplifies warmed vertical compaction by altering the backfilling process. The technique allows for delivery of a single backfill injection of gutta-percha once the apical segment of canal has been obturated.

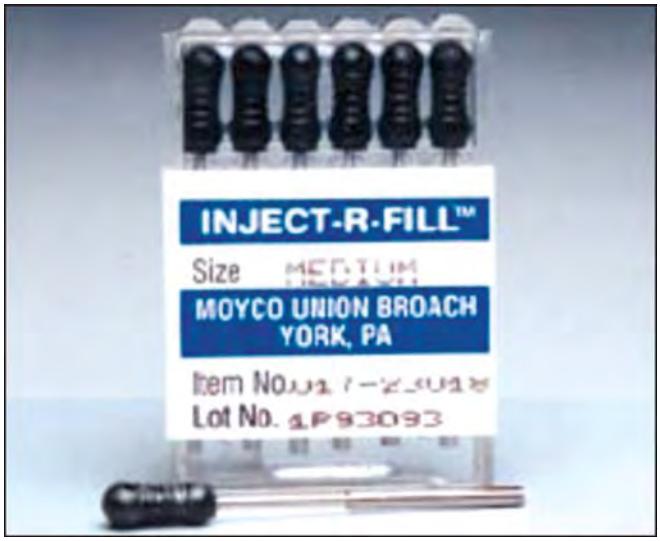


Fig. 15.18: Inject- R-Fill

Apical segment of canal can be obturated using any technique including lateral compaction, traditional warm vertical compaction or system B.

If a cold lateral technique is used, the gutta-percha extruding from the canal must be heat severed at sufficient depth so a plugger can be used to compact the remaining heat softened segment in apical third of canal. If the system B / vertical compaction is used the method already results in apically compacted segment.

Calamus Flow Obturation Delivery System (Fig. 15.19)

Designed for Tactile Control and Easy Clean-up

The ergonomically designed handpiece and easy-touch activation cuff of the Calamus flow obturation delivery system allow control over the flow and temperature of filling material into the canal. Slender, pen-like handpiece is comfortable to hold and designed to allow tactile sensation, visibility and access.

Activation cuff around the circumference of the handpiece allows easy initiation of the flow of filling material by depressing any flat portion of it. The cuff can be released to stop the flow.

Clean-up is also simple because the gutta-percha is neatly packed in drop-in, drop-out disposable cartridges leading to comfort and control with minimized cleaning and maintenance.

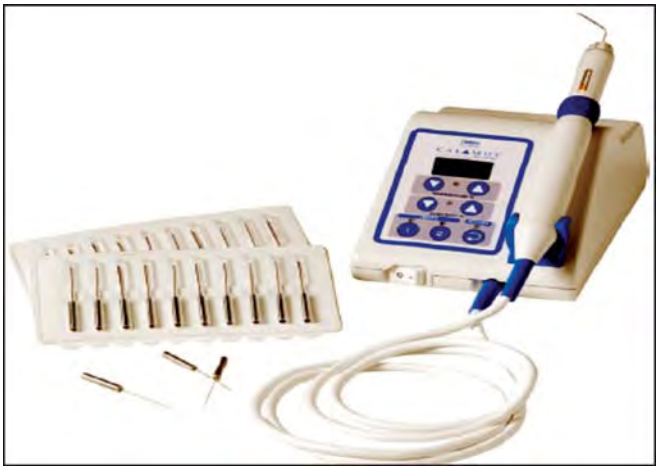


Fig. 15.19: Calamus System

Calamus single gutta-percha cartridges are designed for single-patient use. They are convenient, disposable and reduce the risk of cross contamination when used as directed.

Filling material indicator allows the monitoring of the amount of filling material remaining.

Easy-to-use console allows control of the heating temperature and flow rate of the filling material; preset buttons allow to lock in desired settings.

Microseal System (Fig. 15.20)

The MicroSeal technique developed by Dr John McSpadden, and introduced in 1996 consists of a nickel-titanium (NiTi) spreader, a NiTi condenser, a gutta percha heater, a gutta-percha syringe, and a special formulation of gutta percha available in cones or in cartridges. It is considered a thermomechanical compaction technique that uses a rotary instrument to plasticize the gutta percha and move it within the root canal apically and laterally. The MicroSeal system is able to preserve a conservative preparation and provide an adequate penetration by the obturation instruments in the apical third.

It fills all dimensions of the canal system independent of canal morphology using a master cone technique that is familiar, controllable and clinically reliable.

Features include:

- Low-fusing gutta-percha specifically designed to flow with pressure, heat or both.

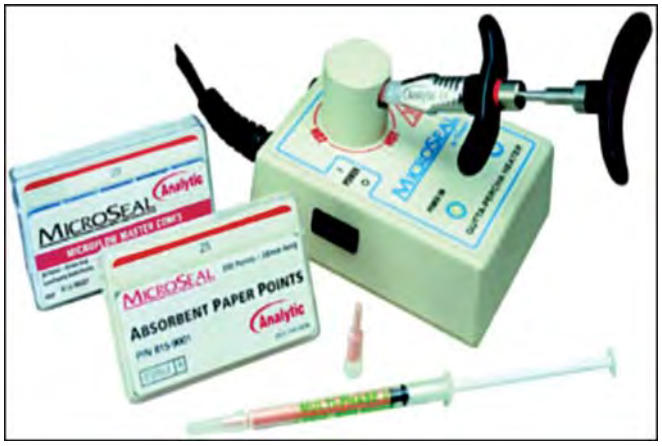


Fig. 15.20: Microseal System

- Minimal compaction required
- Canal irregularities filled

Disadvantages

- Cost
- Control of flow
- Heat
- Difficulty in post space preparations.

Thermafil technique: After canal varification with Thermafil verifier, the corresponding size gutta percha cone is heated in Thermafil oven.

It is carried to the canal and placed. After post obturation radiograph, it is cut near canal orifice with inverted cone bur with highspeed handpiece.

- Condensers are stiff enough to go full length, flexible enough to slide around curvatures and easy to custom-fit without distortion. May also be used to enhance traditional lateral and vertical techniques.

SOLID CORE CARRIER OBTURATION

Thermafil: Johnson (1978) (Fig. 15.21)

Thermafil is a patented endodontic obturator consisting of a flexible centrally carried, sized core tapered to match standard endodontic files, which is uniformly coated with refined and tested alpha-phase gutta-percha.

Initially, stainless steel carriers were introduced. They were heated in a flame and then introduced into the canal. Later the material was changed to titanium or radiopaque plastic. Plastic core carrier obturators can only be heated in special oven, known as the "Therma prep" (Fig. 15.22).

It is recommended that all three types of obturators should be heated in the oven at 115°C for 3-7 minutes depending on the size of the carrier, which ranges from size No. 20 to 140. A new recent innovation has been a new version which heats the filling segments faster within 20-40 sec.

Advantages

- Rapid
- Less strain

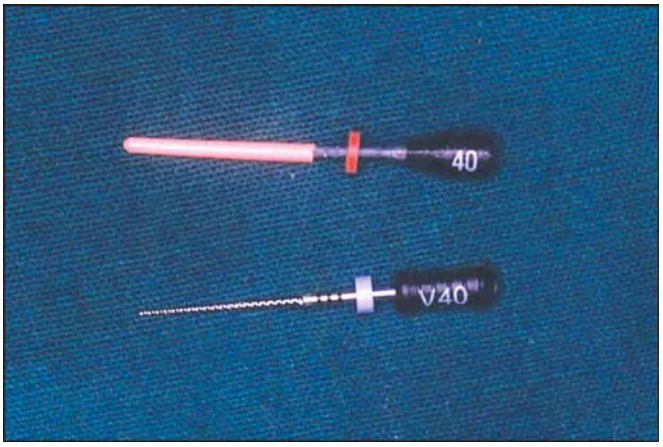


Fig. 15.21: Thermafil Obturator and Verifier

Fig. 15.22: Therma Prep Oven

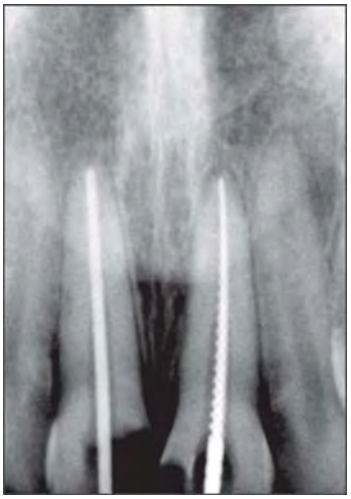


Fig. 15.23: Verifier

Size Verification

One of the deficiencies, as compared with gutta-percha stick, is that there is no way to test if the master cone fits properly by verifying using a radiograph when using Thermafil. This is true for the other thermoplastic techniques, as well. For this reason, it was suggested that a finger spreader be fit, as it would be when using thermoplastics, so that the presence of an apical dentin matrix and removal of the elbow is verified prior to insertion of the softened mass.

For use with thermafil, a size verification kit is available to perform this function. This kit is a collection of the plastic obturators only, without the gutta-percha portion. If the obturator will seat into the apical matrix of the preparation, then, it is assumed that the softened gutta-percha coating can be packed to the correct position. Fitting an obturator of the same size will provide this feature, but it might not verify the presence of an apical dentin matrix. To accomplish that purpose, it is suggested that a verification obturator two or three sizes smaller than the MAF be tried in. If this stops at the working length, the matrix is confirmed (Fig. 15.23).

Size verifiers are designed with flutes which also makes them excellent for minor apical shaping. Made of nickel titanium, these verifiers can be heat sterilized for reuse.

Carriers

The carrier used in the original technique was a file used for preparation. Following the production of Thermafil, manufactured stainless steel files were coated with softened gutta-percha, shaped and cooled and then boxed for delivery. In cases where a post was required for restoration, a significant amount of this metal file needed to be removed, as with a sectioned silver point. This was not easy to accomplish and there was fear that attempts at "twisting-off" or partial removal might decrease the apical seal.

Recently, the metal carrier has been replaced by plastic. This material can be more easily removed after being placed in a canal, with the Prep bur a smooth round, non-cutting bur that removes the plastic by heat. Much easier and safer than attempting the twist-off with stainless steel for the preparation of the post space. Thermacut burs are simple stainless steel blunt burs used to create enough frictional heat to separate the Thermafil carrier from its handle and are available in packs of six as a separate item (Figs 15.24 and 15.25).

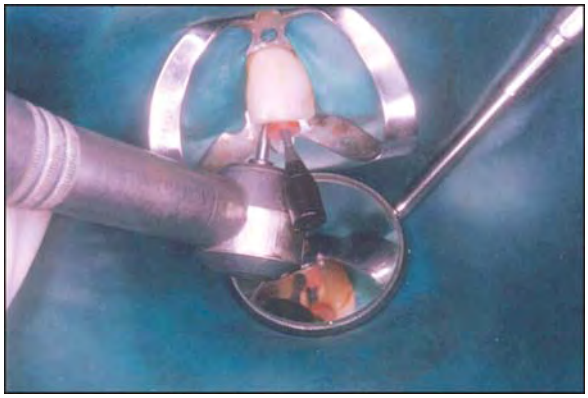


Fig. 15.24: Cutting the obturator core above the coronal orifice

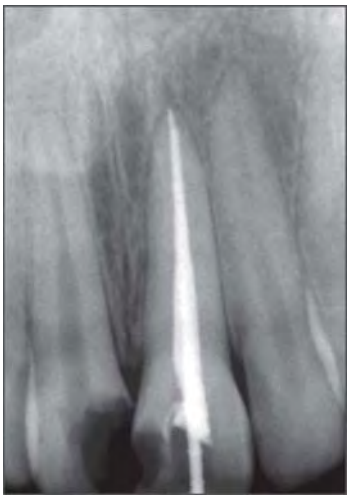


Fig. 15.25: Themafil obturation before severing core

Plastic obturators sizes # 25 through # 40 are composed of liquid crystal plastic; sizes #45 and larger are made from polysulfone polymer. Both plastics are nontoxic, highly stable polymers, which are well tolerated by the body. The liquid crystal plastic is resistant to solvents, but the polysulfone is susceptible to most of the solvents used in dentistry, including chloroform. This means that when plastic carrier fillings are re-treated, the larger canals do not offer much problem. For the smaller canals, the gutta-percha may be dissolved easily by solvents and then the trick is to hook the carrier with a Hedstrom file for removal.

There have been some recent changes. In the degree of taper of the gutta-percha content of the filling segments. Sizes 20 through 40 are available with tapers of 0.04, 0.06, 0.08 and 0.10, whereas sizes 35, 50 and 70 are available in 0.12 tapers.

Thermafil Plus Obturators

These flexible, patented endodontic obturators in 25 mm length feature a plastic, grooved core, coated with "alpha phase" gutta-percha. And are Designed to deliver a three-dimensional fill in one minute (Fig. 15.26). Vertical grooved core provides better backflow of the gutta-percha and easier retrieval, should retreatment become necessary.

Thermafil Plus Oven

This specially, designed heat source for heating thermafil plus endodontic obturators, gives fast, uniform, predictable results. Heats obturators in as little as 17 seconds. A built-in timer alerts with an audible signal that thermafil plus is at optimal temperature.

Fig. 15.26: X-ray showing thermafil obturation

LIGHT SPEED METHOD (SIMPLIFIL GUTTA-PERCHA)

Light speed is the name of the company which manufactures endodontic equipments. A two phase obturation technique has been proposed by Light Speed technology (Texas). In this technique apical 5 mm gutta-percha is attached to a metal core and carried to the apical portion of the canal. Once placed, the carrier is turned and removed, leaving a gutta-percha plug.

The second phase uses a rotary instrument to backfill the remainder of the canal with the Ketac-endo and a single gutta-percha cone. The technique was first studied by Santos DM et al in 1999.

Method

The First Phase

A gutta-percha cone, the same size as the master apical rotary (MAR) instrument is selected. [MAR: is the final apical size of the instrument which is used to prepare the canal last]. The canal and the gutta-percha plug are coated with sealer.

The plug is inserted and vertically condensed to working length by using moderate apical pressure. The carrier is removed by turning the handle counter clockwise until the plug is released.

The Second Phase

A Light Speed backfill instrument is used to carry the Ketac endo sealer into the canal orifice. This is rotated at 1000-2000 rpm and advanced apically till the apical gutta-percha plug was reached.

The instrument is then removed against one wall. This is repeated till the canal is filled with the sealer. The master cone is then coated with the sealer and placed till the apical plug. The excess gutta-percha is then removed at the level of canal orifice.

The Light Speed technique is similar to the sectional method described by Grossman and Coolidge. The difference with this technique is that

slight apical force seats the tapered plug into a parallel apical preparation.

DENSFIL THERMAL ENDODONTIC OBTURATION SYSTEM

Densfil's patented endodontic obturator consists of a flexible central carrier that is uniformly coated with a layer of refined and tested alpha phase gutta-percha. Unlike traditional gutta-percha, alpha phase provides the ideal match to the solid core technique because it becomes adhesive when heated and plasticizes at a lower temperature. The carriers are available in biocompatible, radiopaque medical-grade plastic or titanium.

Densfil Plastic and Titanium Obturators

Plastic core obturators are made from biocompatible, nontoxic, radiopaque medical grade plastic. Densfil plastic carriers are available in sizes #20 to #140. Post placement is simplified using Densfil plastic carriers.

Densfil titanium obturators are available in sizes #20 to #60.

Densfil Size Verifier

The Densfil plastic size verifier helps determine the correct obturator size to use for the obturation procedure.

DensHeat Oven (Fig. 15.27)

The DensHeat oven offers predictable, stable controlled heat for obturator preparation. Up to six obturators can be heated at one time.

JS QuickFill (Fig. 15.28)

This system is designed for a thermomechanical solid core gutta-percha obturation technique.

This system has titanium core devices resembling latch type drills. These are coated with alpha phase gutta-percha. These are then fitted to the prepared root canal and then, the sealer is applied. As the instrument spins in the canal with regular low speed, latch type handpiece frictional heat is liberated. This heat plasticizes gutta-percha and it is also compacted.

After compaction either the compactor may be removed and final compaction done with hand plugger or the titanium core may be left in place and separated by an inverted cone bur.

Fig. 15.27: DensHeat Oven

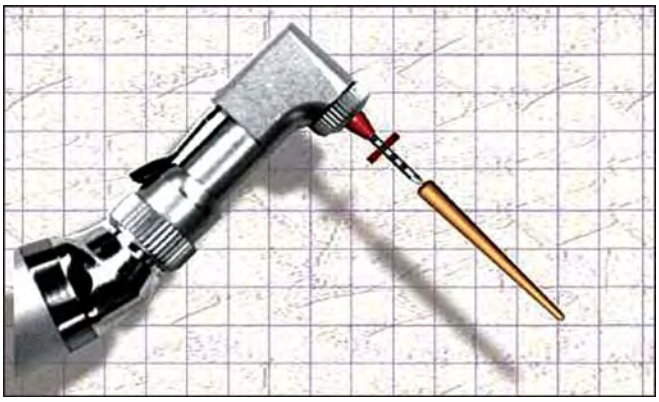


Fig. 15.28: JS QuickFill

TRIFECTA SYSTEM (FIG. 15.29)

The Trifecta technique combines the delivery of SuccessFil gutta-percha to the apical extent of preparation using a carrier followed by the use of injectable Ultrafil gutta-percha. Studies have shown that thermoplasticised gutta-percha can replicate the intricacies of the root canal system and achieve a seal equal to, if not superior to, other obturation methods. Despite the enhanced adaptation of thermoplasticised gutta-percha to root canal walls, numerous studies have shown that the use of root canal sealer is still required with warm techniques to achieve the best possible seal.

The Ultrafil system consists of pre-filled, disposable cannules of gutta-percha with a 22-gauge needle

Fig. 15.29: Trifecta system

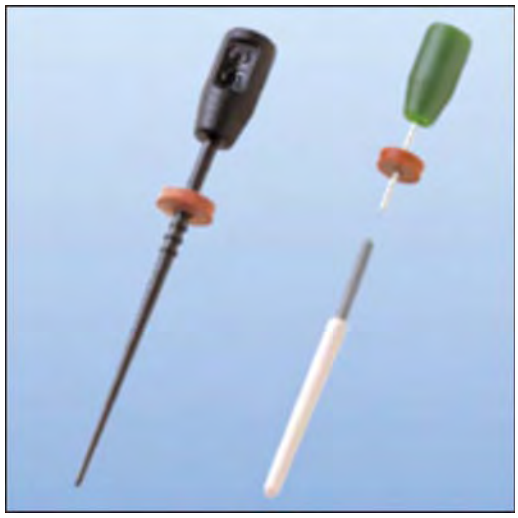


Fig. 15.30: Soft core verifier and obturator

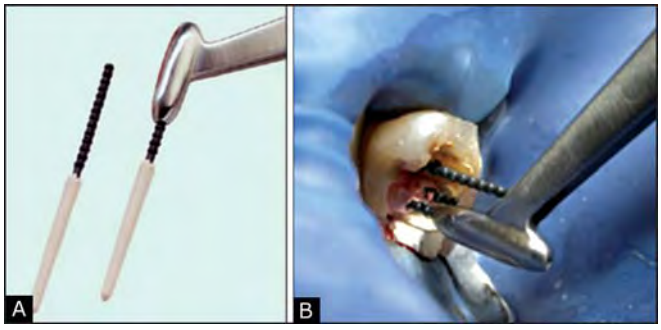
attached, a cordless pressure syringe and a portable heater. The gutta-percha is available in three viscosities: Regular, Firm and Endoset to provide a degree of versatility for filling canals.

SOFT-CORE OBTURATOR FOR ROOT FILLING (FIGS 15.30 AND 15.31)

The principle behind the Soft-Core Obturator is simply a radiopaque plastic carrier covered with thermoplastic gutta-percha. The plastic carrier is available in ISO sizes 20-100.

1. Plastic core with endo stop—The plastic core is tapered, which means that it becomes larger toward the plastic handle. This conicity ensures that the plastic core is sufficiently flexible to negotiate curved canals. The length of the core is 24 mm. The coronal 6 mm of the core is hollow to accommodate the metal insertion pin.

   A rubber endo stop is provided to indicate the working distance measurement. The plastic core and gutta-percha are radiopaque.
2. Plastic handle with a metal insertion pin—The injection molded plastic handle is color-coded according to the size of the obturator. The stainless steel insertion pin is 9 mm long and is permanently attached to the plastic handle. The hollow portion of the plastic core surrounds 6 mm of the pin.
3. Outer layer of thermoplastíc—Natural GP gutta percha. The gutta percha is reversible thermoplastic. This means that it becomes soft and highly adhesive when heated to temperatures above approx 100°C. When cooled, it returns to a firm, rigid state. Another heating will once again make the gutta-percha soft and adhesive.



Figs 15.31A and B: Soft core technique

A Soft-Core Obturator is a core of biocompatible plastic, sized according to ISO standards and coated with thermoplastic gutta percha. A single unit is all that is needed to totally obturate a root canal. It is used to ensure a proper fit in the root canal for the chosen obturator size. The Verifier is made of plastic and has the exact dimension as the same size obturator core. Both the Obturator and the Size Verifier have a rubber stop to indicate the working distance measurement.

Use of the Size Verifier is highly recommended, unless using a rotary file system with a taper of 0.04 or greater for shaping the root canal. In these cases, the Size Verifier is unnecessary since the rotary files have a greater taper, or conicity, than the actual obturator core.

The Soft-Core Obturator is available in following sizes: #20, 25, 30, 35, 40, 45, 50, 55, 60, 70, 80, 90 and 100.

The Technique

1. Choose a plastic carrier which will fit slightly loose in the actual root canal.
2. Heat the guttta-percha in a Soft-Core Oven.
3. The plastic carrier is sufficiently flexible to negotiate curved canals and works like a spreader for the gutta percha. It will fill approx 2/3 of the root filling. The tapered plastic carrier ensures lateral pressure during insertion to assist in filling any lateral canals present with the flowable gutta percha.
4. The color-coded handle with the metal insertion pin is removed after insertion in the root canal. This leaves the coronal part of the plastic carrier hollow, which will make future post space preparation easier.

ULTRASONIC PLASTICIZING

Cavitron With PR-30 Insert

Initially recommended by Moreno in 1977. He used a Cavitron scaler with a P 30 insert. This can be used only in anteriors.

Procedure

Primary point is placed
↓
Unit is placed besides gutta-percha
↓
The ultrasonic unit with the rheostat set at right angles is activated for 3-4 seconds
↓
The ultrasound thermal energy released by vibrating motion of the ultrasonic file plasticizes the gutta-percha
↓
The file is removed and the spreader is immediately inserted to make space for new cones
↓
Obturation is completed

Joiner in 1989 found that the heat produced was 6.35°C in 6.3 seconds by this method. He thus concluded that the heat produced by the Cavitron would not be harmful.

ENAC

The Enac ultrasonic unit has also been used with a certain degree of success by Baumgartner in 1997.

In this unit the spreader is attached. There had spreader penetrated the gutta-percha more easily than did the finger spreader and the energized spreading led to a more homogeneous mass with less stress and less apical microleakage.

However, there is 19.1°C rise in temperature as it takes 141 seconds to plasticize the mass.

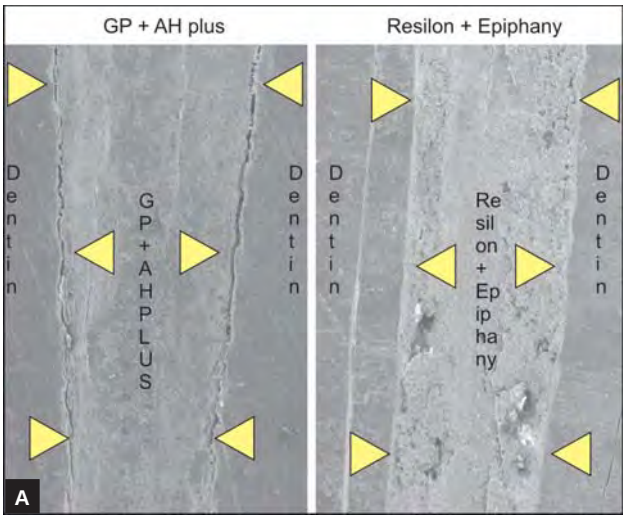
RESILON (FIG. 15.32)

Resilon is a resin based obturation system introduced as an alternative to gutta-percha. It consists of a soft resin core material (resilon) composed of polymerase of polyester, difunctional methacrylate resin, bioactive glass and radiopaque fillers and a resin sealer (Epiphany). The Resilon system consists of master cones in different tapers, a dual-cure sealer, a thinning resin, a self-etch primer, and pellets for injectable back filling.

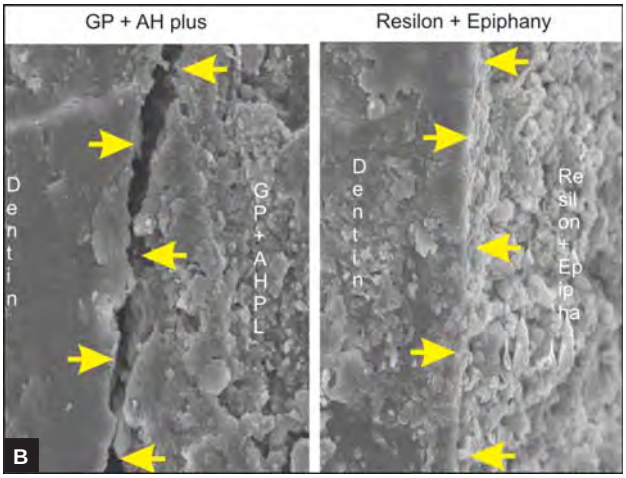
With this filling system, the primer bonds to the dentin wall, while the sealer bonds to both the primer and the filling points forming a "Monoblock" (Figs 15.33 to 15.36). This configuration eliminates shrinkage and subsequent gaps; it also significantly decreases leakage, strengthens the root, and increases resistance to root fracture.

Additionally, the biocompatible, radiopaque material may be removed for retreatment if necessary with present methods of gutta-percha removal. Resilon Research LLC introduced it at the 2003 ADA Annual Session. Numerous papers were presented that confirmed the safety and efficacy of Resilon.

Fig. 15.32: Resilon system



Low magnification (X 50)



High magnification (X 1000)

Figs 15.33A and B: SEM photographs showing comparison between the adaptation of Resilon and lateral condensation to the root canal wall

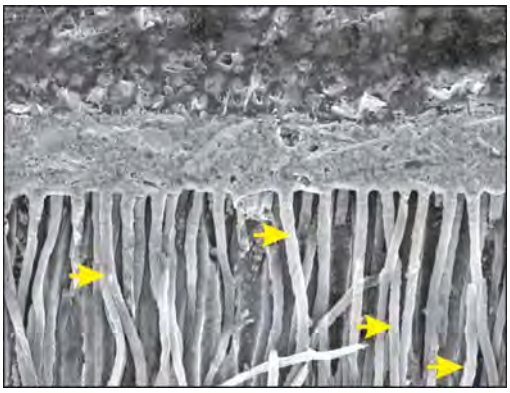


Fig. 15.34: Resilon sealer tags

Fig. 15.35: Primer

Fig. 15.36: Sealer

Technique

- Existing procedures are used for irrigation with sodium hypochlorite and peroxide-based irrigants.
- After the last sodium hypochlorite flushing, dry the canal(s). EDTA is placed into the canal for 1 minute to remove the smear layer. After washing with water, the canal is rinsed with 0.12 percent chlorhexidine gluconate and dried with paper points. Any fluid remaining in the dentinal tubules will enhance bonding, since this is a wet bonding system, hence do not desiccate the canals with ethyl alcohol.
- Select and sterilize the Resilon points similar to that for gutta points.
- Place points in the canals and check with a radiograph.

Composition

Resilon Cones and Pellets
(Figs 15.37 to 15.39)

- Polymers of polyester
- Difunctional methacrylate resin
- Bioactive glass
- Radiopaque filler
- Coloring agent

Fig. 15.37: Resilon cones

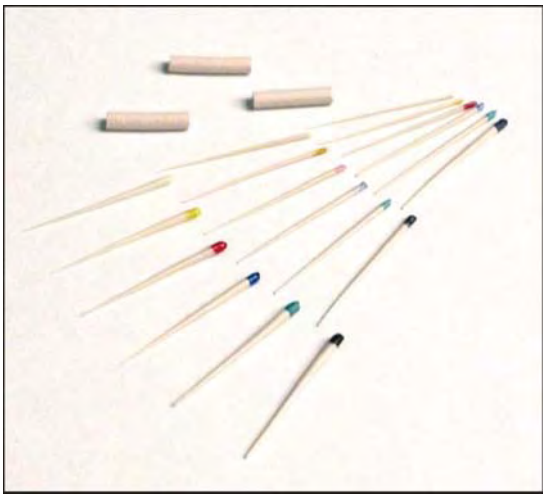


Fig. 15.38: Resilon cones and pellets

- Hydrophilic acidic monomer solution in water
- AMPS
- UDMA, PEGDMA, EBPADMA, BISGMA RESIN
- Silane treated bariumborosilicate glasses
- Barium sulphate, silica, calcium hydroxide, bismuth oxychloride with amines, peroxide
- Photo initiator, stabilizer, pigments

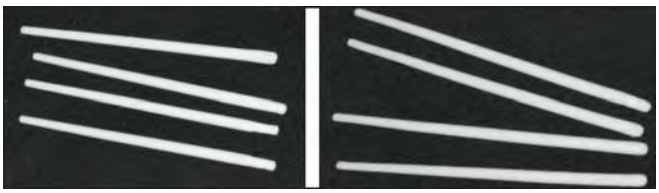
Handling (Fig. 15.39)

Fig. 15.39: Flexibililty of Resilon

Sterilization (Fig. 15.40)

Fig. 15.40: Sodium hypochlorite sterilization of Resilon cones

Radio-opacity (Fig. 15.41)



Resilon *Gutta percha*

Fig. 15.41: Radio-opacity

Obturation Procedure (Fig. 15.42)

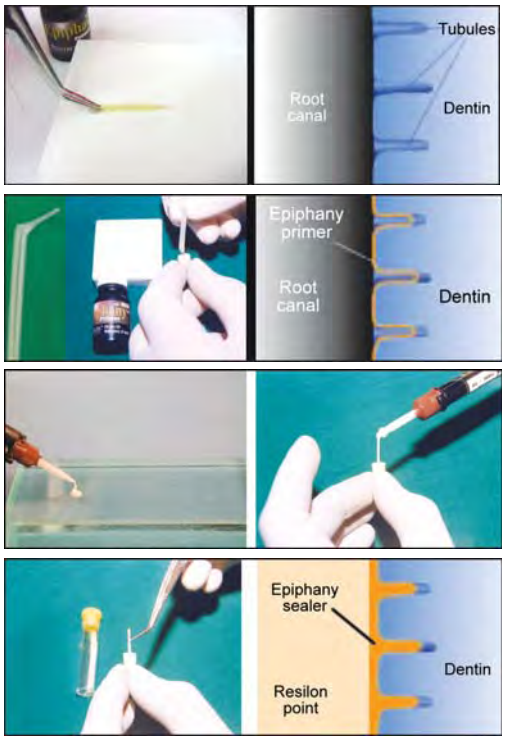


Fig. 15.42: Obturation technique

Coronal Sealing

- The primer is placed into the canals with paper points and removed after 30 seconds.
- The canals are coated with the sealer. The sealer viscosity can be adjusted with thinning resin to suite preference.
- The points are coated with sealer and placed to length.
- After checking the cone placement radiographically and making any necessary adjustments, proceed with condensation. This can be accomplished by any of existing methods.
- After condensation, the excess is removed with a hot plugger and the coronal surface is light cured for 40 seconds, creating an instant coronal seal (Fig. 15.43). The cement then chemically cures in 25 minutes, sealing the entire canal from orifice to apex.

SIMPLIFIED ALTERATIONS TO THE EXISTING SYSTEMS TO USE RESILON

Currently available obturation systems can be used to condense Resilon. Adjustments in temperature settings, however, are required as follows:

- System B (SybronEndo) temperature is set at 150°C and power is set at 10 Elements Obturation unit (SybronEndo). Temperature is set at 150°C for the down pack. The extruder is set to the synthetic setting, allowing it to default to the correct temperature.
- Obtura II (Obtura Spartan). The temperature is set to 170°C for 25-gauge needles and to 160°C for 20- and 23-gauge needles.
- Thermique (Parkell) Heat setting is adjusted to one below 200°C, providing a temperature of 150°C at the end of the tip.

Fig. 15.43: Curing for immediate coronal seal

Guttaflow

GuttaFlow unites gutta percha and sealer in one product and has material properties of excellent flow characteristics, no contraction, and good biocompatibility. An application system has been developed, which makes simple, safe and hygienic handling possible.

Composition

1. Polydimethylsiloxane
2. Silicone oil
3. Paraffin oil
4. Platinum catalyst
5. Zirconium dioxide
6. Nano-silver
7. Gutta-percha powder

GUTTA FLOW SYSTEM (FIGS 15.44 TO 15.46)

It is the first fluid gutta-percha which does not shrink. For the accurate dosage and good mixing a special cap was developed, with which no contamination can occur.

It permits very simple handling, since only one master point is needed. The material has excellent flow characteristics, which make an optimal distribution in the root channel as well as lateral channels and

Fig. 15.44: Capsule

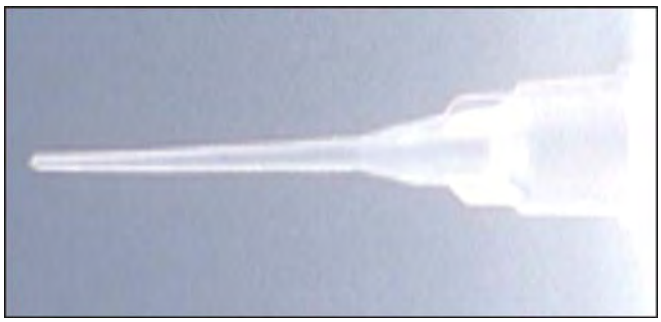


Fig. 15.45: Cannula Tip (ISO size 50)

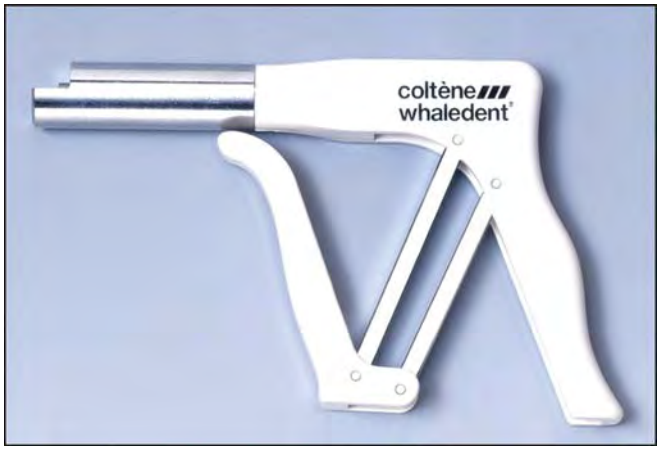


Fig. 15.46: Dispenser

Isthmus. Gutta Flow can be easily removed during retreatment

GUTTA FLOW MANIPULATION (FIGS 15.47A TO D)

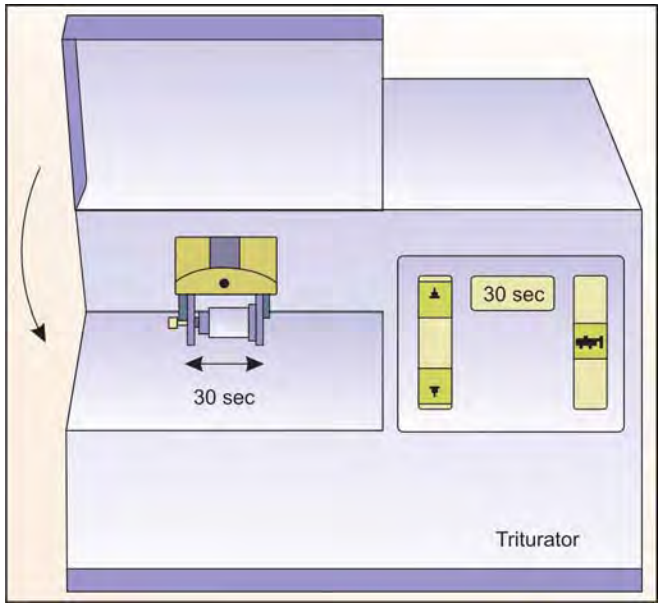


Fig. 15.47A: Triturate

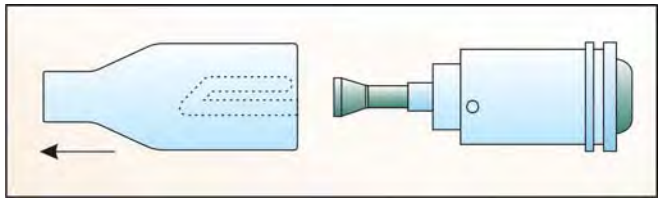


Fig. 15.47B: Open the cover

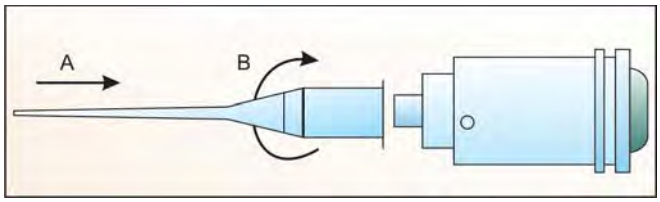


Fig. 15.47C: Fix the cannula

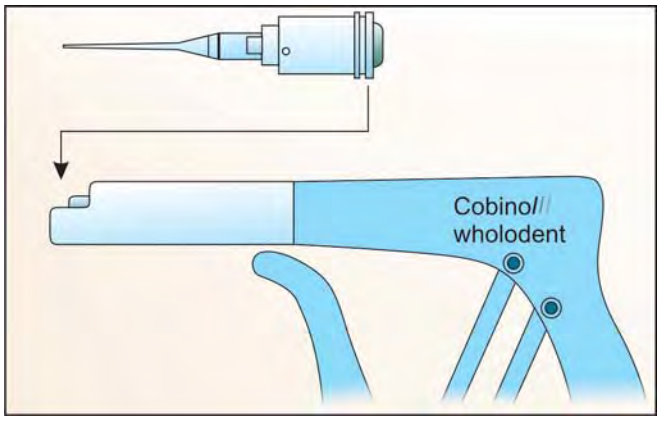


Fig. 15.47D: Load the capsule onto gun

GUTTA FLOW STEP-BY-STEP APPLICATION

Diagrammatic Representation (Figs 15.48 and 15.49)

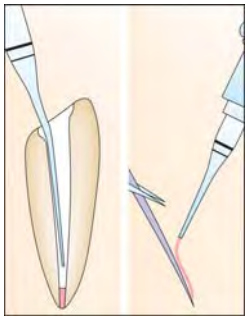


Fig. 15.48A: Inject in the apical third/ coat the master cone

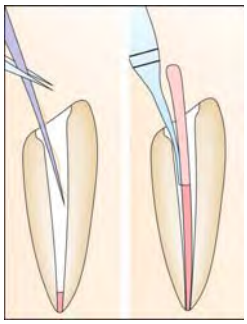


Fig. 15.48B: Place the cannula along the side of the cone, Backfill

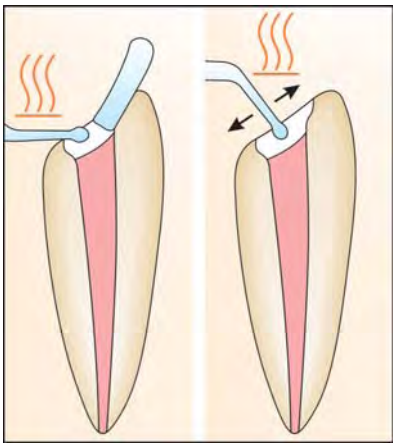


Fig. 15.49: Sear Excess Gutta-percha

CLINICAL PICTURES

See Figures 15.50A to D.

Endo REZ System (Fig. 15.51)

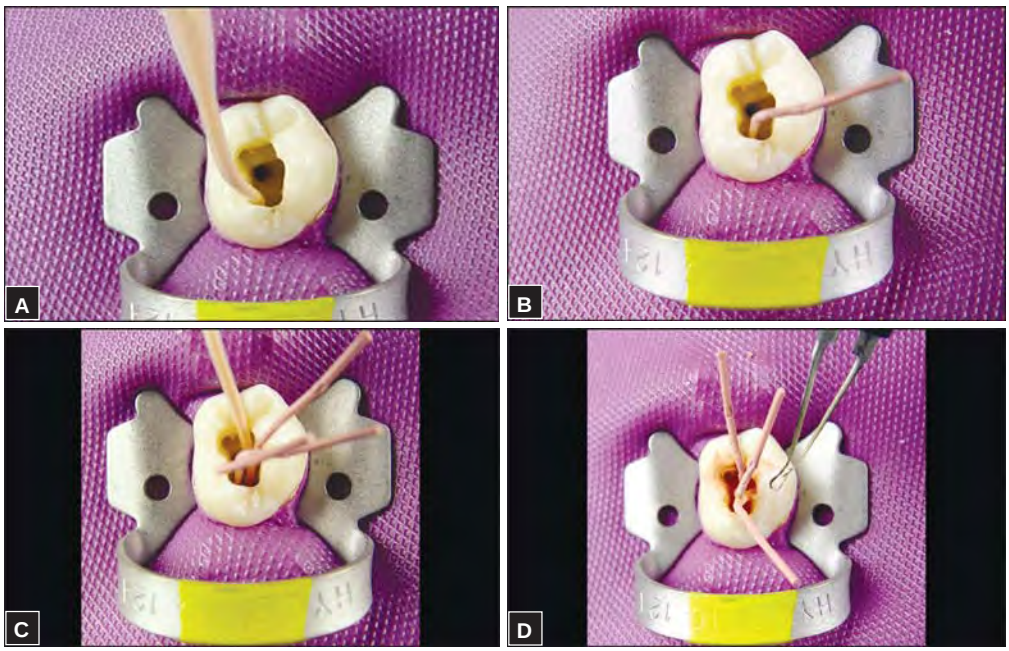
Endo REZ is a two part dual cure set endodontic sealer and filler based on UDMA resin—the same type of resins used today as orthopedic bone cements. So biocompatibility is assured. It displays the same radiopacity as GP, thus, simplifying radiographic interpretation. This system is said to aid in Air Displaced Obturation (ADO), the fastest growing obturation technique.

Endo REZ Dual Cure is easily and conveniently mixed 14 times via a specifically designed auto mix nozzle that attaches directly into a unique Skinni Syringe. The precise diameter of the Skinni Syringe guarantees that the exact amount of pressure is applied to the Endo REZ to allow safe and controlled delivery into the canal. The use of 29G Navitip cannulas, allow the smooth delivery of Endo REZ Dual Cure into the canal—filling from the apex up with no air entrapment. Once canals have been filled 1/3 of the way, gutta-percha can be placed into the canal to complete the obturation process. When the root canal is successfully filled with Endo REZ Dual Cure, the 2-3 mm coronal portion can be set initially by using your curing light. The rest of the Endo REZ sealer in the canal will chemically set in 12-15 minutes.

Active GP System (Fig. 15.52)

In this system glass ionomer is incorporated into the gutta-percha(8%).This is a highly radiopaque system used as a single cone technique with EndoSequence system.

Active GP sealer is used. Highly active surface prepared to chemically adhere to the Activ GP glass ionomer sealer.



Figs 15.50A to D: GuttaFlow technique

Fig. 15.51: Endo REZ

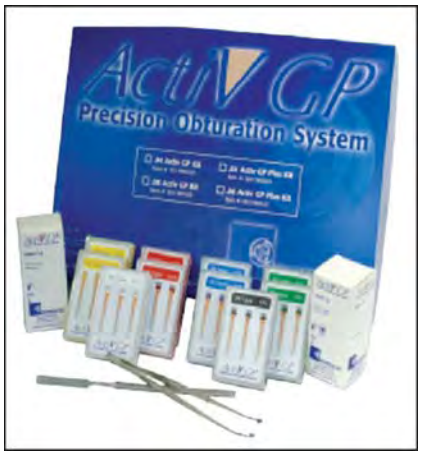


Fig. 15.52: Active GP System

Active GP Sealer has been formulated with an extended 12 minute working time.

The sizes of Active GP gutta-percha points are consistently accurate, and verified as such by laser-measurement to match your 0.04 or 0.06 tapered EndoSequence* file system.

Active GP Plus employs calibration rings for easy depth measurement and a unique barrel handle which when placed using the placement instrument (transporter), facilitates easy placement into the canal (Fig. 15.53).

Chemical and micromechanical adhesion between the canal walls, the Active GP sealer and the Activ GP gutta-percha points results in a Monobloc within the canal, completely sealing the canal from orifice to apex.

Dentin Chip Apical Filling (Fig. 15.54)

Formation of apical dentinal plug during canal preparation against dentinal chips constitutes the "new technique," of obturation. The result is a "biologic seal" rather than a mechanochemical seal. The fact that dentin filings will stimulate osteo or cementogenesis is well documented. Gottlieb and Orban noted cementum forming around

Fig. 15.53: Active GP System for depth measurement

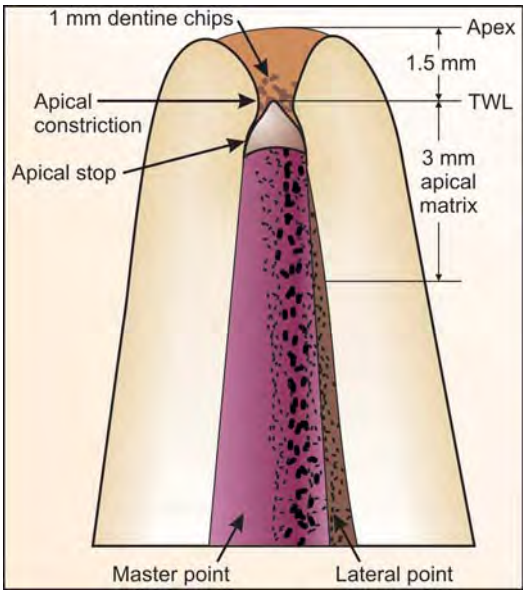


Fig. 15.54: Dentin chip apical filling

dentin chips in the PDL as early as 1921. Baume et al described "osteodentin" closings but incomplete calcification across all of their histologic serial sections.

Once the canal is totally debrided and shaped and the dentin is no longer "contaminated," a Gates-Glidden drill or Hedstroem file is used to produce dentin powder in the central position of the canal. These dentin chips may then be pushed apically with the butt end and then the blunted tip of a paper point.

They are finally packed into place at the apex using a premeasured file one size larger than the last apical enlarging instrument. One to two mm of chips should

block the foramen. Completeness of density is tested by resistance to perforation by a No. 15 or 20 file. The final gutta-percha obturation is then compacted against the plug.

Efficacy of Dentin Chip Apical Obturation: One of the positive effects of a dentin plug endodontic filling is the elimination of extrusion of sealer or gutta-percha through the apex. This reduces periradicular inflammation. It also provides an apical matrix against which gutta-percha is compacted. The group at the University of Connecticut found, however, that they could not totally block the apical foramen with chips following vital pulpectomy. On the other hand, they did report "hard tissue formation was common but no total closure occurred," and that "tissue response to dentin chips was generally favorable".

SUGGESTED READING

1. Bailey GC, Ng YL, Cunnington SA, Barber P, Gulabivala K, Setchell DJ. Root canal obturation by ultrasonic condensation of gutta-percha. Part II: an in vitro investigation of the quality of obturation. Int Endod J 2004;37:694-98.
2. Berry KA, Loushine RJ, Primack PD, Runyan DA. Nickel-titanium versus stainless-steel finger spreadersin curved canals. J Endod 1998;24:752-54.
3. Bowman CJ, Baumgartner JC. Gutta-percha obturationof lateral grooves and depressions. J Endod 2002;28: 220-23.
4. Buchanan LS. Filling root canal systems with centered condensation: concepts, instruments and techniques. Endod Prac 2005;8:9-15.
5. Chogle S, Mickel AK, Huffaker SK, Neibaur B. An in vitro assessment of iodoform gutta-percha. J Endod 2005;31: 814-16.
6. Clinton K, Van Himel T. Comparison of a warm gutta percha obturation technique and lateral condensation. J Endod 2001;27:692-95.
7. Gesi A, Raffaelli O, Goracci C, Pashley DH, Tay FR, Ferrari M. Interfacial strength of resilon and gutta-percha to intraradicular dentin. J Endod 2005;31:809-13.
8. Gencoglu N. Comparison of 6 different gutta-percha techniques (part II): Thermafil, JS Quick-Fill, Soft Core, Microseal, System B, and lateral condensation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:91-95.
9. Gordon MPJ, Love RM, Chandler NP. An evaluation of .06 tapered gutta percha cones for filling of .06 taper prepared curved root canals. Int Endod J 2005;38:87-96.
10. Grossman LI. Endodontic Practice. Philadelphia: Lea and Febiger, 1978.
11. Guess GM, Edwards KR, Yang ML, Iqbal MK, Kim S. Analysis of continuous-wave obturation using a singlecone and hybrid technique. J Endod 1993;29:509-12.
12. Gutmann J, Witherspoon D. Chapter 9: Obturation of the Cleaned and Shaped Root Canal System. Pathways of the Pulp, 7th edn. St Louis: Cohen and Burns, 2002;293-364.
13. Huumonen S, Lenander-Lumikari M, Sigurdsson A, Ørstavik D. Healing of apical periodontitis after endodonticbtreatment: a comparison between a siliconebased and a zinc oxide-eugenol-based sealer. Int Endod J 2003;36:296-301.
14. Kardon BP, Kuttler S, Hardigan P, Dorn SO. An in vitro evaluation of the sealing ability of a new root canal-obturation system. J Endod 2003;29:658-61.
15. Levitan ME, Himel VT, Luckey JB. The effect of insertion rates on fill length and adaptation of a thermoplasticised gutta percha technique. J Endod 2003;29:505-08.
16. Lui JN, Sae-Lim V, Song KP, Chen NN. In vitro anti-microbial effect of chlorhexidine-impregnated gutta percha points on Enterococcus faecalis. Int Endod J 2004;37:105-13.
17. Lohbauer U, Gambarini G, Ebert J, Dasch W, Petschelt A. Calcium release and pH-characteristics of calcium hydroxide plus points. Int Endod J 2005;38:683-9.
18. Saw LH, Messer HH. Root strains associated with different obturation techniques. J Endod 1995;21:314-20.
19. Shipper G, Ørstavik D, Teixeira FB, Trope M. An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer-based root canal filling material (Resilon). J Endod 2004;30:342-47.
20. Schaeffer MA, White RR, Walton RE. Determining the optimal obturation length: a meta-analysis of the literature. J Endod 2005;31:271-74.
21. Silver GK, Love RM, Purton DG. Comparison of two vertical condensation obturation techniques: touch 'n heat modified and system B. Int Endod J 1999;32:287-95.
22. Tagger M, Tamse A, Katz A, Korzen BH. Evaluation of the apical seal produced by a hybrid root canal filling method, combining lateral condensation and thermatic compaction. J Endod 1984;10:299-303.
23. Tay FR, Loushine RJ, Monticelli F,Weller RN, Breschi L. Effectiveness of resin-coated gutta-percha cones and dual-cured, hydrophilic methacrylate resin-based sealer in obturating root canals. J Endod 2005;31:659-64.
24. Villegas JC, Yoshioka T, Kobayashi Ch, Suda H. Intracanal temperature rise evaluation during the useage of the System B: replication of intracanal anatomy. Int Endod J 2005;38:218-22.
25. Villegas JC, Yoshioka T, Kobayashi C, Suda H. Threestep versus single-step use of system B: evaluation of gutta-percha root canal fillings and their adaptation to the canal walls. J Endod 2004;30:719-21.
26. Wu MK, Tigos E, Wesselink PR. An 18-month longitudinal study on a new silicon-based sealer, RSA RoekoSeal: a leakage study in vitro. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94:499-502.
27. Zmener O. Tissue response to a new methacrylatebased root canal sealer: preliminary observations in the subcutaneous connective tissue of rats. J Endod 2004;30: 348-51.
28. Zmener O, Banegas G. Clinical experience of canal filling by ultrasonic condensation of gutta percha. Endod Dent Traumatol 1999;15:57-59.

16 Importance of Coronal Sealing

The impact of coronal leakage on the outcome of root canal treatment has been known for nearly 90 years. Previously research focused on the quality of the preparation and obturation to achieve long-term treatment success, and the effects of poor coronal restorations on endodontic outcomes received little attention. Pulpal and periradicular diseases develop when microorganisms and/or their by-products contaminate these tissues. Therefore, a major goal of both preventive and restorative dentistry is to prevent penetration of microorganisms into the coronal pulpal space and root canal system. The root canal system, once invaded, may harbor many species of microorganisms, their by-products and variable amounts of inflamed or necrotic tissues.

Even well filled root canals can be recontaminated. This can occur when:

1. There has been a delay in the restoration of a tooth following root canal treatment.
2. The coronal temporary filling, placed immediately following root canal treatment, is compromised.
3. The tooth is fractured and the canal system is exposed prior to final restoration.
4. The final restoration, regardless of type or design, lacks ideal marginal integrity or cannot withstand the forces of occlusal function.
5. Recurrent decay is present at the restoration margin(s).

In these situations, the coronal and/or radicular portion of the root canal system is exposed to oral micro flora and their by-products. Both *in vitro* and *in vivo* investigations show that post endodontic coronal leakage can allow bacterial penetration in the filled root canal system, causing recontamination and failure of treatment.

Preventing Coronal Leakage

Clinicians have four major opportunities to prevent coronal leakage in endodontically treated teeth:

- Temporary seal of the root canal system, during and after treatment.
- Choice and integrity of the final tooth restoration.
- Timeliness in restoration and establishment of atraumatic occlusion.
- Long-term follow-up to evaluate the integrity of the definitive treatment.

Temporary Seal of the Root Canal System, During and After Treatment

A faulty temporary filling during or following root canal treatment is one of the major causes for coronal leakage (Figs 16.1 and 16.2). Failure of the temporary

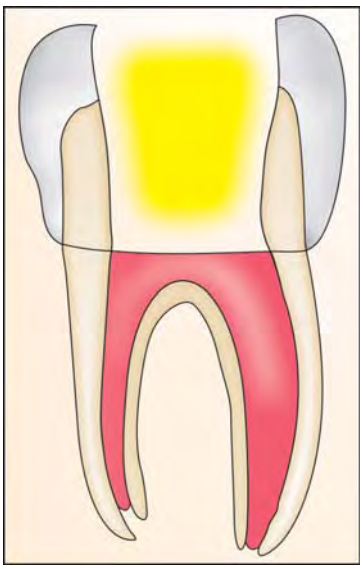


Fig. 16.1: Improper coronal sealing

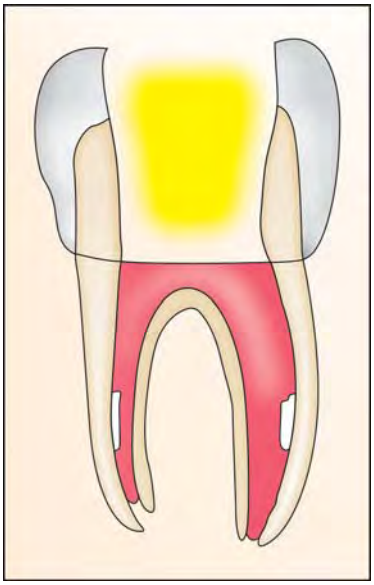


Fig. 16.2: Disintegration of gutta-percha after five years due to improper coronal sealing

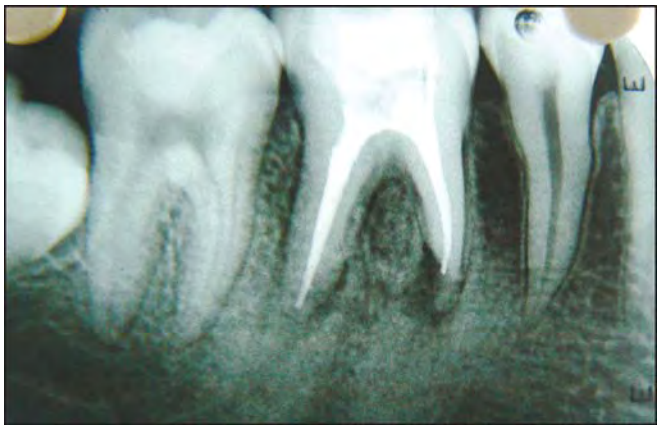


Fig. 16.3: Radiograph showing improper coronal seal after obturation

restoration can be due to an inadequate thickness of material, improper placement of the material and failure to evaluate the occlusion after placement (Fig. 16.3). Commonly used temporary filling materials are Cavit, TERM and IRM. A bonded material such as composite resin or glass ionomer cement is preferred. Temporary materials may also be used. Mineral trioxide aggregate (MTA) may also be used. There is probably some benefit in using a material that is clear so that the restorative dentist can see the underlying obturating material if re-entry is needed into the canal system.After placing a cotton pellet in the pulp chamber, practitioners should place temporary materials in the access cavities with no gaps or voids. The cotton must be minimal and placed securely into the access cavity prior to placement of the filling to prevent a lifting or dislodgement of the temporary material.

All temporary materials leak to some extent. The zinc oxide/calcium sulfate materials are more resistant to microleakage than the zinc oxide eugenol materials, probably because of setting expansion and water sorption. Although the zinc oxide eugenol materials tend to leak more, they possess antimicrobial properties, making them more resistant to bacterial penetration. If the canal is infected and wet, an intracanal medicament, such as calcium hydroxide, should be placed in the root canal. This antimicrobial material may act as a barrier to the ingress of microorganisms into the root canal system. The medicament should not be used as a substitute for a well-placed temporary restoration, nor should it be used to enhance the long-term use of temporary restorations. Materials used between appointments or immediately following root canal treatment are temporary in nature and do not provide an impervious barrier for long periods.

Most studies that have examined the effectiveness of these materials have done so under artificial conditions those do not mimic true clinical parameters. Therefore, their use is based on *in vitro* outcomes and expectations, as opposed to their *in vivo* realities and true capabilities. A minimum of four millimeters of material thickness provide an adequate seal. Based on current evidence, this seal can be expected to remain effective no longer than three weeks. Allowing a temporary material to remain longer than this period is an invitation to coronal leakage and future failure.

Resin based temporary materials must be bonded to provide an effective seal, because they undergo polymerization shrinkage of 1 to 3 percent. This is offset by the fact that they swell as they absorb water. Generally, bonded resin materials provide the best initial seal, but lack antimicrobial properties. They require more steps and more time to place than materials such as IRM or Cavit. Bonded resins are recommended for temporization that is likely to last more than 2 to 3 weeks. Resin modified glass ionomer materials are also a good choice for long-term temporization, because they provide a bond to dentin and enamel, and many have antimicrobial properties.

Teeth requiring temporary post/crowns are a particular challenge, because of the difficulty in obtaining a good seal. To minimize the chances of contamination of the obturating material, a barrier may be placed over it with a self-curing material. The post space should be restored as soon as possible and it may be beneficial to flush the post space with an antimicrobial irrigant when the temporary post is removed.

Endodontically treated posterior teeth, unlike anterior teeth, usually require a bonded core and the placement of a post when there is need to enhance core retention. Bonded cores using amalgam, core pastes and reinforced composites are ideal core buildup materials. Glass ionomers do not have sufficient strength to provide the necessary integrity for cores in posterior or anterior teeth. When using a core buildup in either anterior or posterior teeth, the interface of the core material and the tooth structure must be at a position at least two millimeters above the free gingival margin to allow for the placement of a crown on at least two millimeters of sound tooth structure (ferrule effect). The margin of the crown must not impinge on the biological width. Some readers may wonder what this imperative has to do with coronal leakage. If there is impingement on the biological width, the patient may have discomfort, especially during brushing or flossing, and as a result may not clean this area properly. Not only does this predispose to bacterial accumulation and plaque formation but also to periodontal pocketing, recurrent decay and ultimate loss of marginal integrity with pursuant coronal leakage. Treatment planning for appropriate restoration of endodontically treated teeth is only part of the equation for success.

Timeliness in Restoration and Establishment of Atraumatic Occlusion

The restoration of an endodontically treated tooth should commence as soon as possible after root canal treatment. Delaying definitive restoration allows teeth with a periradicular radiolucency to demonstrate healing prior to restoration; however, this action is unnecessary with today's advancements in root canal treatment.

An important issue with the restoration of endodontically treated teeth is to ensure the tooth is in atraumatic occlusion. If aberrant forces are present, the coronal seal of the restoration, or the seal of the post or core, can be disrupted in time and could result in coronal leakage or tooth fracture.

Long-term Follow-up to Evaluate the Integrity of the Definitive Treatment

Follow-up evaluation of all endodontic and subsequent restorative procedures is essential because of coronal leakage and its impact over time (Figs 16.4 and 16.5). Either the general dentist or endodontist can do the follow-up evaluation. This process includes evaluation of signs, symptoms, radiographic indicators of pathosis and examination for the evidence of coronal leakage, e.g. recurrent decay, loss

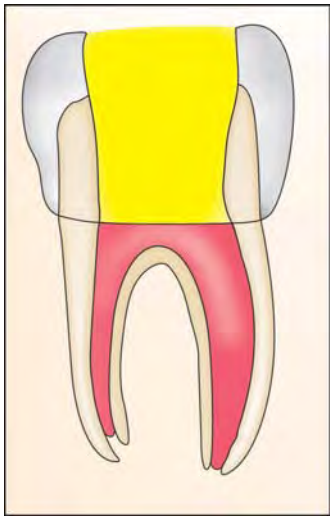


Fig. 16.4: Proper coronal sealing

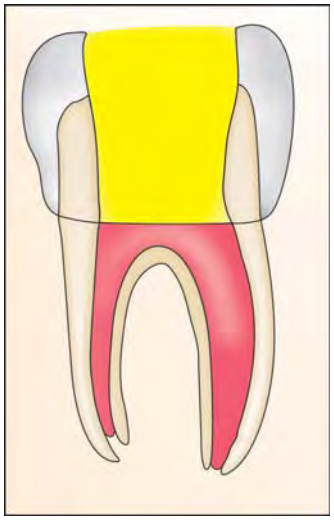


Fig. 16.5: After 5 years

of marginal integrity and other parameters. Prevention of coronal leakage in endodontically treated teeth is most important for patients who rely on the combined expertise and quality care of dentist/endodontist colleagues.

SUGGESTED READING

1. Barrieshi-Nusair KM, Hammad HM. Intracoronal sealing comparison of mineral trioxide aggregate and glass ionomer. Quintessence Int 2005;36(7-8):539-45.
2. Cruz EV, Shigetani Y, Ishikawa K, Kota K, Iwaku M, Goodis HE. A laboratory study of coronal microleakage using four temporary restorative materials.Int Endod J. 2002;35(4):315-20.
3. Galvan RR Jr, West LA, Liewehr FR, Pashley DH. Coronal microleakage of five materials used to create an intracoronal seal in endodontically treated teeth. J Endod 2002;28(2):59-61.
4. Heling I, Gorfil C, Slutzky H, Kopolovic K, Zalkind M, Slutzky-Goldberg I. Endodontic failure caused by inadequate restorative procedures: review and treatment recommendations.J Prosthet Dent 2002;87(6):674-78.
5. Pappen AF, Bravo M, Gonzalez-Lopez S, Gonzalez-Rodriguez MP. An in vitro study of coronal leakage after intraradicular preparation of cast-dowel space. J Prosthet Dent 2005;94(3):214-18.
6. Sauaia TS, Gomes BP, Pinheiro ET, Zaia AA, Ferraz CC, Souza-Filho FJ.Microleakage evaluation of intraorifice sealing materials in endodontically treated teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;102(2): 242-6. Epub 2006 Apr 21.
7. Shindo K, Kakuma Y, Ishikawa H, Kobayashi C, Suda H. The influence of orifice sealing with various filling materials on coronal leakage Dent Mater J 2004;23(3): 419-23.
8. Suprabha BS, Sudha P, Vidya M. A comparative evaluation of sealing ability of restorative materials used for coronal sealing after root canal therapy. J Indian Soc Pedod Prev Dent 2001;19(4):137-42.
9. Verissimo DM, Vale MS.Methodologies for assessment of apical and coronal leakage of endodontic filling materials: a critical review. J Oral Sci 2006;48(3):93-98.
10. Wells JD, Pashley DH, Loushine RJ, Weller RN, Kimbrough WF, Pereira PN. Intracoronal sealing ability of two dental cements. J Endod 2002;28(6):443-47.

After an adequate root canal treatment, post-endodontic restoration is a very important phase for the functioning of the endodontically treated tooth in the oral cavity. The planning for the post endodontic restoration should be discussed before initiating the root canal therapy to determine the durability of the final restoration affecting the prognosis of the tooth in terms of functional life.

Previously, metals such as gold, stainless steel, titanium, and base metal alloys were commonly used as post and core materials. These may be used as either Prefabricated, or Custom made.

With the development of fiber technology, non-metallic fiber posts have been introduced in the market recently.

POST

The post is defined as the segment of the restoration inserted into the root canal to aid in retention of the core component. It is a rigid material placed in the root of a tooth. It can be fabricated from metals or non-metallic substances. The post is important in the restoration of non-vital teeth that have significant coronal damage and have insufficient sound tooth structure remaining above the periodontal attachment to secure a coronal restoration.

Indications for Post

Primary purpose is to retain a core in a tooth with extensive loss of coronal tooth structure.

Post should only be used when other options are not available to retain a core.

A. Anterior Teeth

1. Significant destruction of tooth structure with loss of structurally important areas: marginal ridges, cingulum, incisal edge.
2. If an endodontically treated anterior tooth needs a crown, a post is often indicated (Schwarz and Robbins). In most cases, the remaining coronal tooth structure is quite thin after it has received root canal treatment and has been prepared for a crown. Anterior teeth must resist lateral and shearing types of forces, and the pulp chambers are too small to provide adequate retention and resistance without a post. Thus, the amount of remaining coronal structure and the functional requirements of the tooth determine whether an anterior tooth requires a post.

B. Molars

1. Significant destruction of coronal tooth structure.

C. Premolars

1. Significant destruction of coronal tooth structure.
2. Moderately damaged tooth structure with presence of small pulp chamber.
3. High functional demands. As these teeth are more often subjected to lateral forces than molars during mastication, especially as part of RPD/FPD, they require a post more often than molars.

Contraindications for Post

A. Anterior Teeth

1. Mild to moderate coronal damage, e.g. presence of small proximal lesions with intact cingulum and marginal incisal edge.

2. Intact teeth.
3. Sufficient remaining tooth structure after crown preparation.

B. Molars

1. Mild to moderate coronal damage where the large pulp chamber can provide retention or other modalities such as pins or amalgam coronal-radicular restorations can be used.
   Molar teeth receive predominantly vertical rather than shear forces. Unless a large percentage of coronal tooth structure is missing, posts are rarely required in endodontically treated molars.

C. Premolars

1. Sufficient remaining coronal tooth structure.
2. Tooth has short clinical crown and functions similar to molars (not much lateral forces).
3. Tooth is not an abutment for FPD/RPD and has sufficient coronal tooth structure.

Components (Fig. 17.1)

Restorations for endodontically treated teeth are designed to replace the missing tooth structure and to protect the remaining tooth structure from fracture. When there is significant loss of tooth structure, a post and core restoration is indicated to support and retain the crown.

The final configuration of the restored tooth includes four parts:

1. Residual tooth structure and periodontal attachment apparatus.
2. Post material, located within the tooth.
3. Core material, located in the coronal area of the tooth.
4. Definitive coronal restoration.

Functions

1. Retention of restoration
2. Protection of remaining tooth structure

The foremost purpose of the post is to provide retention for the core and coronal restoration. It also serves a protective function by dissipating the masticatory forces along the length of the root, thereby equally distributing the stresses and providing some relief at the margins. The post itself does not strengthen the root. On the contrary, the tooth is weakened if extensive dentin is sacrificed to place a large diameter post.

Ideal Properties of the Post

- Maximum protection of the root (Fig. 17.2).
- Adequate retention within the root.
- Maximum retention of the core and crown.
- Maximum protection of the crown margin (cement seal).

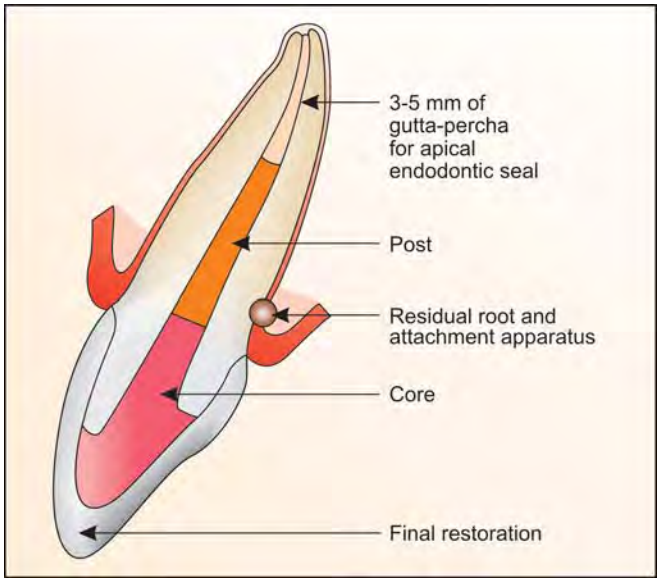


Fig. 17.1: Components of a restored tooth

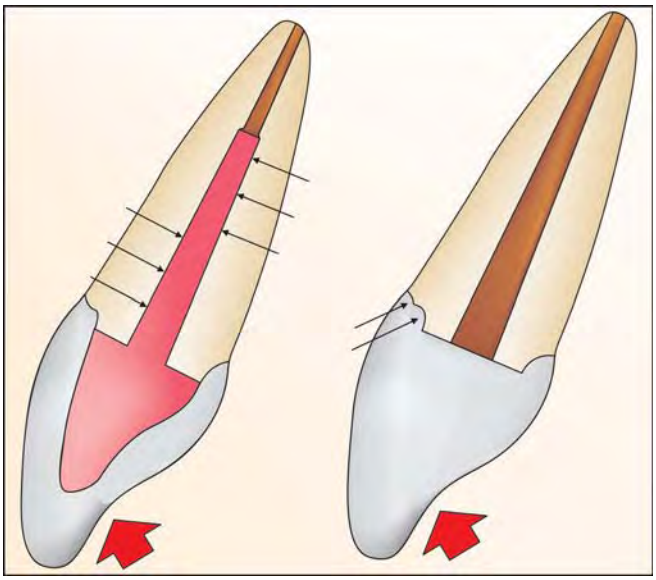


Fig. 17.2: Protective function of post

- Esthetics
- High radiographic visibility
- Retrievability.
- Biocompatibility.

Types of Posts

I. Metallic posts
   1. Custom cast posts
   2. Prefabricated posts.
      a. Passive.
         – Tapered
         – Parallel
      b. Active.

II. Non-metallic posts
   1. Carbon fiber posts
   2. Tooth colored posts
      – Fiber reinforced posts.
      – Ceramic and zirconia posts.

Materials Used

i. *Metals:*
   a. Custom-cast posts:
      i. Gold alloys
      ii. Chrome-cobalt alloys
      iii. Nickel-chromium alloys
   b. Prefabricated posts:
      i. Stainless steel
      ii. Titanium
      iii. Brass

ii. *Non-metals:*
   a. Carbon-fiber
   b. Fiber-reinforced:
      i. Glass fiber
      ii. Quartz fiber
      iii. Woven Polyethylene fiber
      iv. Ceramic and zirconia

Material Requirements

Selection of materials for posts is very important for clinical success. Functions of endodontic posts can be realized only when the following features are adequately incorporated into their design:

- Stiffness
- Strength
- Fatigue characteristics, and
- Corrosion resistance

Stiffness of the posts is an extremely important characteristic. Insufficient post stiffness permits excessive distortion of the restoration margins during function and, in the case of castings, leads to cement breakdown and recurrent decay (Fig. 17.3). In addition to the modulus of elasticity, the dimension of the post also contributes to overall post stiffness. The smaller the diameter, the lower the stiffness. Consequently, a higher modulus of elasticity allows the use of smaller diameter posts. Therefore, a material with higher modulus is preferred for an endodontic post (Fig. 17.4).

Yield strength indicates the onset of permanent deformation. A material with high yield strength will withstand a higher force before a permanent change in shape, and hence, the potential for permanent change of shape of the post and margins will be minimized during function.

Fatigue characteristics of the material used for post fabrication should be good because a post supporting

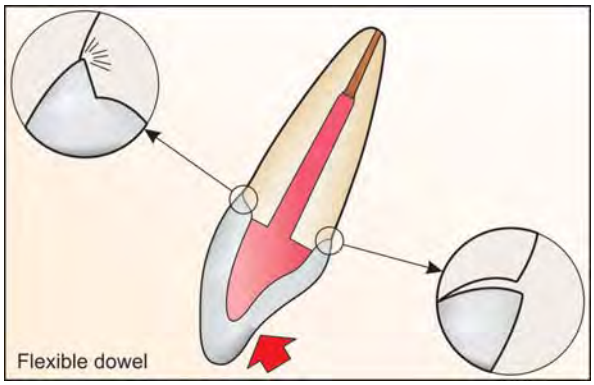


Fig. 17.3: Disadvantages of flexible post: A dowel fabricated from a flexible material will allow crushing of cement or dentin near the facial margin with opening of the lingual margin

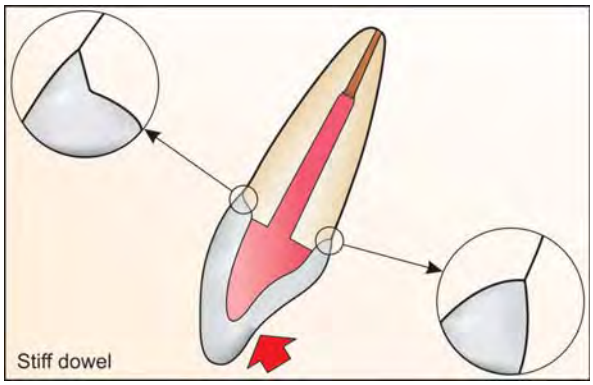


Fig. 17.4: Advantages of rigid post: A dowel fabricated from a stiff material will tend to resist failure at the coping margins by transferring stresses apically

a crown will be subjected to repeated cycles of loading and unloading during mastication. Stress concentrations, inclusions and corrosion pits will affect the fatigue behavior of posts.

The importance of corrosion resistance in metallic posts is not readily realized, as the post does not come into direct contact with oral fluids. The interaction between the posts and dentinal fluid produces corrosion products between the post and canal walls. This results in the application of lateral forces to the canal walls, which subsequently may fracture. Corrosion of posts has been implicated and amply documented in longitudinal and oblique fractures of the teeth. Corrosion, however, is not a concern with non-metallic and titanium posts.

CONSERVATION OF TOOTH STRUCTURE

Root Canal

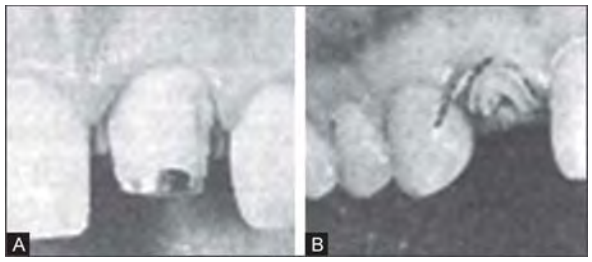
When creating post space, the practitioner should use great care to remove only minimal tooth structure from the canal. Over enlargement can perforate or weaken the root, which then may split during cementation of the post or during subsequent function. The thickness of the remaining dentin is the prime variable in fracture resistance of the root.

Experimental impact testing of teeth with cemented posts of different diameters showed that teeth with a thicker diameter (1.8 mm) post fractured more easily than those with a thinner (1.3 mm) post. Photoelastic stress analysis also showed that internal stresses are less with thinner posts.

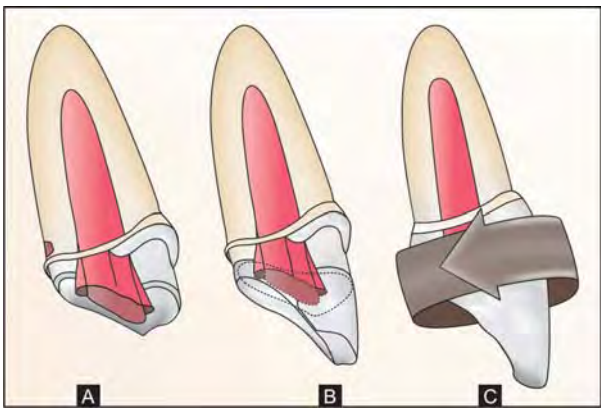
Most roots are narrower mesiodistally than faciolingually and often have proximal concavities that cannot be seen on periapical radiographs. Experimentally, most root fractures originate from these concavities because the remaining dentin thickness is minimal. Thus it is recommended that the root canal be enlarged only the amount necessary to enable the post to fit snugly for strength and retention. Enlargement seldom needs to exceed one or two additional file sizes beyond that used for endodontic treatment.

Coronal Tissue (Figs 17.5A and B)

As much of the coronal tooth structure should be conserved as possible because this helps reduce stress concentration at the gingival margin. The amount of remaining tooth structure is probably the single most important predictor of clinical success.



Figs 17.5A and B: Remaining coronal tooth structure: (A) It is preferable to maintain as much coronal tooth structure as possible, provided it is sound and of reasonable strength, (B) Extensive caries has resulted in the loss of all coronal tooth structure. This is less desirable than the situation in A, because greater forces are transmitted to the root



Figs 17.6A to C: Ferrule effect: The preparation for a dowel core should preserve solid tooth structure (A), the crown preparation finish line should be apical to the dowel core margin (B), enabling the crown to girdle the tooth (arrow) and brace it externally (C).

It has been shown experimentally that if more than 2 mm of coronal tooth structure remains, the post design plays little role in the fracture resistance of the restored tooth. Incorporation of this tooth structure within the final restoration provides the ferrule (Figs 17.6A to C).

RETENTION FORM

Post retention is defined as the ability of a post to resist vertical dislodging forces.

Retention of a post is affected by:

1. Preparation geometry and post design.
2. Post length.
3. Post diameter.
4. Surface texture.
5. Luting agent.
6. Number of posts.

It should be emphasized, however, that there is generally a tradeoff between retention and protection. Maximum retention is not necessarily optimum retention.

1. *Post design and preparation geometry:* Circular canals can be prepared with drills or reamers to give parallel walls or minimum taper, allowing use of parallel-prefabricated post. Elliptical or excessively flared canals cannot be prepared to give parallel walls and require custom cast posts or tapered prefabricated posts.

   Laboratory testing has confirmed that parallel sided posts are more retentive than tapered posts and that threaded posts are the most retentive of all. However, threaded posts are generally not recommended due to the high installation stresses generated. If used, great caution must be exercised.
2. *Post length (Fig. 17.7):* Retention increases with increase in post length. One study shows that retention increases by more than 97 percent when post length equals or is greater than crown length (Sorensen and Martinoff). However, this length must be well within the constraints of tooth length, canal morphology and root diameter in the apical area. Various criteria for post length are:
   1. Minimum of 5 mm of apical gutta-percha fill should be remaining .
   2. Post length should be equal to 2/3rd of root length or greater.
   3. Post length should be at least equal to the crown length.
   4. When bone support is less, the post should extend at least half the length of root in the remaining bone.

   The short post will fail and too long a post will damage the apical seal or lead to perforation if apical third of the root is curved or tapered. Where length is compromised, use of parallel-sided posts over tapered posts or in extreme cases, threaded posts should be considered.
3. *Post diameter (Figs 17.8A and B):* Whether posts are cemented or threaded, diameter makes little difference in retentive ability. This is because posts are not placed in perfect cylindrical canals. In many cases the canal is ribbon or elliptical shaped, resulting in variable cement thickness or lack of total engagement. Thus, diameter variations are of little concern for providing retention.

   Instead, if the post diameter is increased, the amount of remaining dentin between the post and the external surface of the root is decreased. This diminished remaining dentin becomes an area of high stress concentration under load and, consequently, an area with a high potential for failure. Therefore, increasing the diameter in an attempt to increase retention is not recommended. The smallest diameter post that is practical should be used for a given clinical situation.
4. *Surface texture:* A serrated or roughened post is more retentive than a smooth one. Roughening can be done with sandblasting.

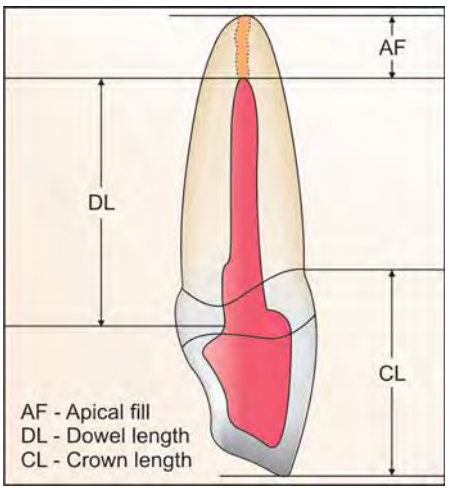
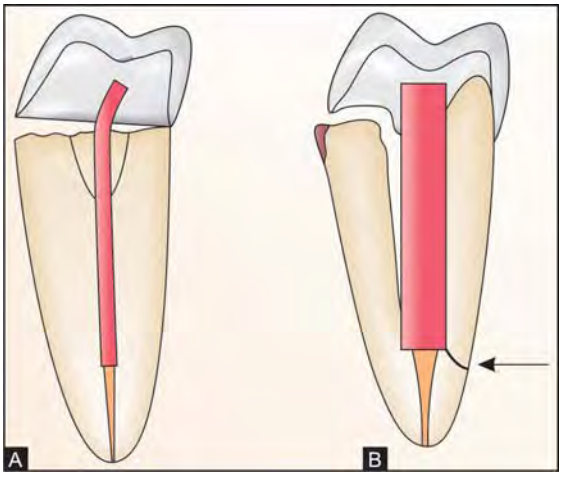


Fig. 17.7: Post length



Figs 17.8A and B: Post diameter: Left weak post and lack of Ferrule break to coronal fracture Right, largest post weakers the tooth making is more susceptile to root fracture, particularly at the apical end of the post (arrow)

5. *Luting agent:* Any of the current luting cements can be successfully used with a post if proper principles are followed. The most commonly used luting agents are: zinc phosphate, resin, glass-ionomer and resin-modified glass ionomer. However, Resin-modified glass ionomer cements should be avoided as they expand on water absorption and may cause root fracture.

   Generally, in the past, zinc phosphate was the cement of choice, but, recent trend has been toward resin cements because they:
   - Increase retention.
   - Tend to leak less than other cements.
   - Provide at least short-term strengthening of the root.

   Disadvantages of resin cements
   - These cements are technique sensitive and require preparation of walls with acid or EDTA and require use of dentin bonding agents, without which no significant increase in retention has been found.
   - Requirement of extra steps such as treatment with EDTA, etching, bonding.
   - Difficulty in delivering etchants and bonding agents deep into the canal. This can overcome by using specially made microbrushes. These are small brushes which can deliver etchants and bonding agents deep into the canal.
6. *Number of posts:* It is possible to place more than one post in teeth with multiple roots. Additional posts may be used, where feasible, to increase retention and retain core material, especially in severely broken down teeth.

Considerations for Posterior Teeth

Relatively long or circular posts should be avoided in posterior teeth with curved ribbon-shaped / elliptical canals. For these teeth, using short posts in divergent canals better provides retention.

If a cast core is used, it can be made in sections that have different paths of withdrawal. Alternatively, the widest canal is selected for the major post and then short auxiliary post spaces are prepared in the other canals with the same path of withdrawal (Fig. 17.9).

RESISTANCE FORM

Resistance is defined as the ability of the post and tooth to withstand lateral and rotational forces.

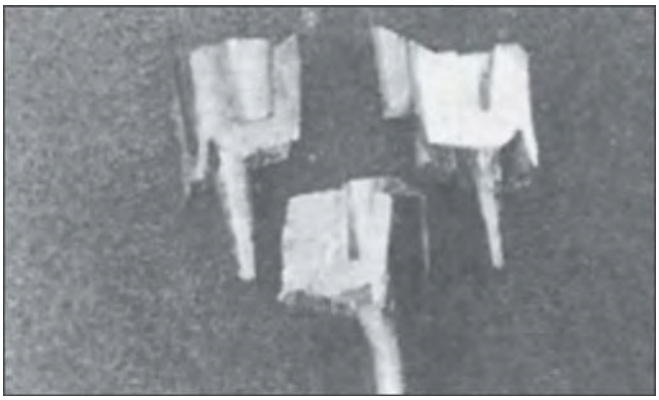


Fig. 17.9: Sections of cast core

Stress Distribution

One of the functions of a post and core restoration is to improve resistance to laterally directed forces by distributing them over as large an area as possible. However, excessive preparation of the root weakens it and increases the probability of failure. The post design should distribute stresses as evenly as possible.

The influence of post design on stress distribution has been tested using photoelastic materials, strain gauges and finite element analysis. From these laboratory studies, the following conclusions have been drawn (Rosenstiel):

1. The greatest stress concentrations are found at the shoulder, (particularly inter-proximally) and at the apex. Dentin should be conserved in these areas.
2. Stress is reduced as post length increases. But excessive length reduces the thickness of dentin at the apical area and hence the fracture resistance decreases.
3. Parallel-sided posts distribute stresses more evenly than tapered posts, which can have a wedging effect. However, parallel posts generate high stresses at the apex.
4. Sharp angles should be avoided as they produce high stresses during loading.
5. High stress can be generated during insertions of smooth parallel-sided posts that have no event for escape of cements. Therefore in these posts, longitudinal grooves (vents) running along the length of the post should be provided to allow escape of cement thus reducing the hydrostatic pressure and generation of stress. Tapered posts are self-venting and generally do not require vents.

6. Threaded posts can produce high stresses during insertion and loading, but they have been shown to distribute stress evenly if the posts are backed off a half-turn.
7. The cement layer results in a more even stress distribution to the root with less stress concentration.

In addition, fiber (carbon and glass) reinforced posts produce more even stress distribution along the lengths of the root than the metal posts.

Rotational Resistance

It is important that a post with a circular cross section not rotate during function. Where sufficient coronal tooth structure remains, this should not present a problem because the axial wall then prevents rotation. When coronal dentin has been completely lost:

- A small groove placed in the canal can serve as an anti-rotational element. The groove is normally placed where the root is bulkiest, usually on the lingual aspect (Fig. 17.10).
- An auxiliary pin on the root face can prevent rotation.
- Rotation of a threaded post can be prevented by preparing a small cavity-half in the post, half in the root and condensing amalgam into it after cementation of the post.
- Additional cemented posts in multirooted teeth.
- Oval or elliptical canals.

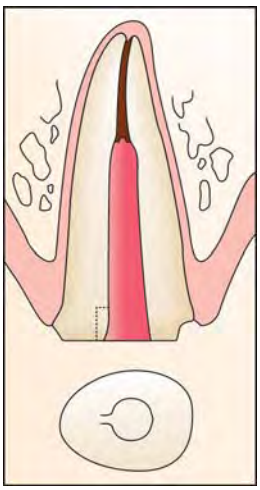


Fig. 17.10: Antirotation groove: Rotational resistance in an extensively damaged tooth can be obtained by preparing a small groove in the root canal. This must be in the path of withdrawal of the post-and-core.

The Ferrule (Fig. 17.11)

Rosen in 1961 described the Extracoronal Brace (ferrule) and defined it as "….a subgingival collar or apron of gold which extends as far as possible beyond the gingival seat of the core and completely surrounds the perimeter of the cervical part of the tooth. It is an extension of the restored crown which, by its hugging action, prevents vertical shattering of the root."

More recently, Sorensen and Engelman (1990) defined Ferrule Effect as "…..a 360° metal collar of the crown surrounding the parallel walls of the dentin extending coronal to the shoulder of the preparation. The result is an elevation in resistance form of the crown from the extension of dentinal tooth structure."

The walls and margins of the crown or cast telescopic coping encasing the gingival 2 mm of the axial walls of the preparation form the ferrule. A properly executed ferrule significantly reduces the incidence of fracture in the non-vital tooth by reinforcing the root at its external surface and also by dissipating force that concentrates at the narrowest circumference of tooth.

As described by several authors, stress in the radicular dentin during function is concentrated to the circumference of the tooth, whereas the stress level is lowest within the root canal (Fig. 17.12). The center of the root is a neutral area with regard to stress concentration, and thus no reinforcement is needed in this area. To reinforce the tooth, incorporating a ferrule into the design of the crown embracing the

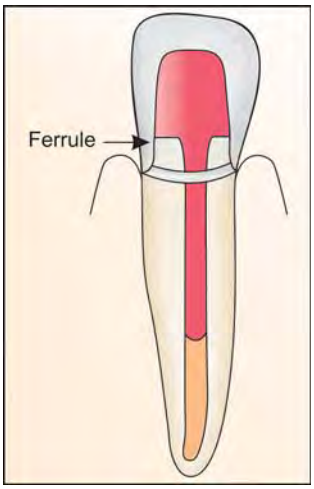


Fig. 17.11: Ferrule effect

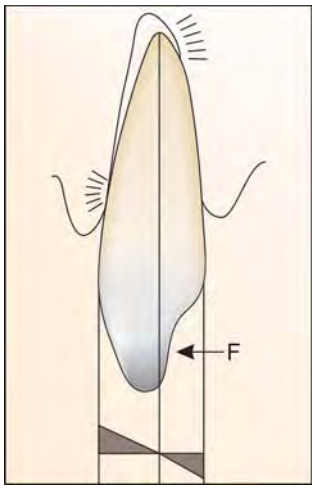


Fig. 17.12: Stress in radicular dentin during function is concentrated to circumference of tooth; stress is lowest within root canal

circumference of the root, protects the root where the maximum forces occur. The ferrule effect is a key factor in the failure of post treated teeth.

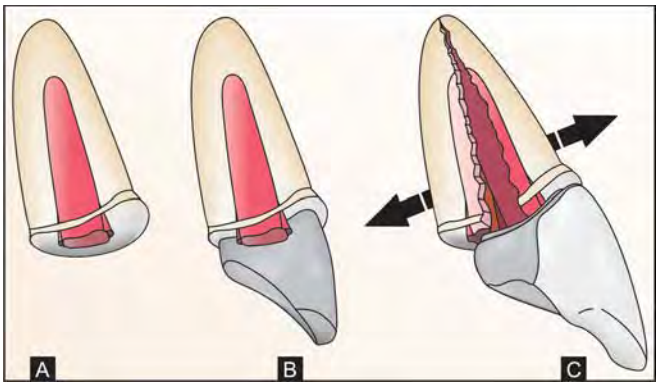
Fracture resistance is significantly increased with increasing ferrule length. The ferrule also resists lateral forces from posts and leverage from crown in function, and it increases the retention and resistance of the restoration. As already stated, presence of a ferrule reduces the influence of post design on the fracture resistance of teeth (Figs 17.13A to C).

To be successful, the ferrule must encircle a vertical wall of sound tooth structure above the margin and must not terminate on restorative material. Both the crown and crown preparation must meet five requirements:

1. A maximum of 2 mm of dentin axial wall height.
2. Parallel axial walls.
3. Metal must totally encircle the tooth.
4. It must be on sound tooth structure.
5. It must not invade the attachment apparatus.

This means that a 4-5 mm height and 1mm thickness of sound suprabony tooth structure should be available to accommodate the periodontal biologic width and the restorative ferrule. A tooth with remaining tooth structure that is insufficient to construct a ferrule should be evaluated for:

- Periodontal crown lengthening surgery, or,
- Orthodontic extrusion,to gain access to additional root surface.



Figs 17.13A to C: Wedging effect of a post in absence of Ferrule: If a tooth is flush with the gingiva (A), fabrication of a dowel core and a crown without encirclement of tooth structure by the crown walls (B), could result in root fracture (C)

The lack of sufficient ferrule in the final restoration forces the core, the post and the root to accept high functional stresses, often resulting in fracture.

METAL POSTS

Custom-Cast Metal Posts

The custom cast post and core has a long history of success in restorative dentistry. However, laboratory studies have consistently shown that the fracture resistance of teeth restored with custom cast posts is lower than that of teeth restored with many different prefabricated posts. In addition, retrospective clinical studies have shown prefabricated parallel posts to have greater clinical success than custom cast posts. Their tapered design exerts wedging forces on the root. This, coupled with the added expense, extra appointment and need for temporization, have made them fall out of favor. Nonetheless, there are studies that report a high rate of success with cast post and cores and they offer advantage in certain clinical situations.

Indications

1. When multiple posts and cores are being placed in the same arch. It is more time and cost effective to prepare multiple post spaces, make an impression and fabricate the posts in the laboratory.
2. When posts and cores are being placed in small teeth, such as mandibular incisors. In these instances, it is difficult to retain the core material on the head of a prefabricated post, as minimal space is available around the post.

3. When the angle of the core must be changed in relation to the post, Prefabricated posts should not be bent, therefore, the custom cast post best fulfills this requirement.
4. When an all-ceramic restoration is placed, it is necessary to have a core that approximates the color of natural tooth structure. If a large core is being placed on in a high-stress situation, resin composite may not be the material of choice due to the fact that it tends to deform under a load. In this circumstance, the post and core can be cast in metal and porcelain can be fired to the core to simulate the color of natural tooth structure. The core porcelain can then be etched with hydrofluoric acid, and the all-ceramic crown can be bonded to the core.
5. In excessively flared and elliptical canals where prefabricated posts may be difficult to use.
6. Cast post and cores are generally easy to retrieve when endodontic re-treatment is necessary.

Perhaps the biggest disadvantage for cast post and cores is in areas that require an esthetic temporary restoration. Temporary post/crowns are not effective in preventing contamination of the root canal system.

When a temporary post and crown is needed, a barrier material should be placed. Examples of barrier materials are GIC, ZOE or self-curing dentin adhesives and composites. They should be placed over the obturating material and the cast post and core should be fabricated and cemented as quickly as possible.

Materials Used (Fig. 17.14)

The commonly used materials are Type III or IV gold alloys. The main constituents of these alloys are gold, copper and silver, with small amounts of palladium, platinum and zinc. These alloys display excellent corrosion resistance, high modulus of elasticity and tensile strength. Strength of these alloys may be increased by appropriate heat treatment.

Non-precious nickel-chromium and cobalt-chromium alloys are also used. They are commonly used for endodontic post designs available in the form of plastic burnout patterns, which are invested and cast. These alloys are much stiffer than cast gold and exhibit higher yield and tensile strength.

PREFABRICATED POSTS (FIG. 17.15)

Prefabricated posts are typically made of stainless steel, nickel-chromium alloy or titanium alloy. They are very rigid and with the exception of titanium alloys, are very strong. Because they are round, they offer little resistance to rotational forces. This is not a problem if adequate tooth structure remains, but if minimum tooth structure remains, anti-rotation features must be incorporated into the post preparation such as slots or pins. A bonded material should be used for core.

Many of the prefabricated posts are made of titanium alloys and some are made of brass. Titanium posts were introduced because of concerns about corrosion. Most of the titanium posts have a

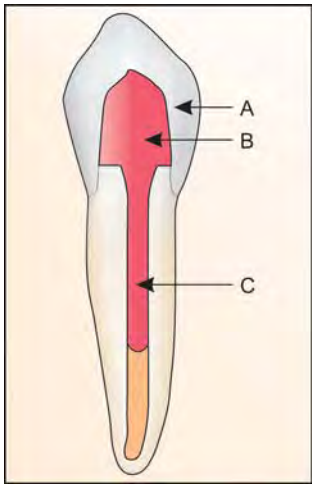


Fig. 17.14: Crown, post and core: (A) Final restoration, (B) Cast-metal core, and (C) Cast-metal post

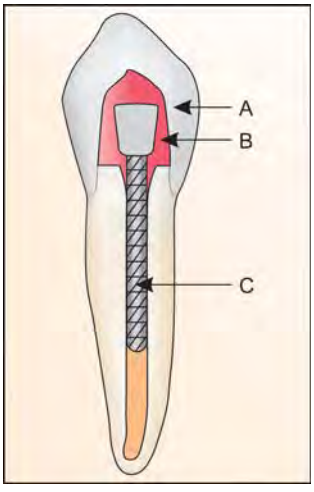


Fig. 17.15: Prefabricated post: (A) Final restoration, (B) Core, (C) Prefibricated post

radiodensity similar to gutta-percha and sealer and are sometimes hard to detect on radiographs. Titanium posts have low fracture strength, which implies that they are not strong enough to be used in thin post channels. Removal of titanium posts can be a problem because they sometimes break when force is applied with a post removal instrument. Extended use of ultrasonic energy may be necessary to remove titanium posts which can be damaging to the tooth or surrounding tissues. For these reasons, titanium and brass posts should be avoided because they offer no real advantages over the stronger metal posts.

Posts or dowels can be generally classified as passive retention or active retention systems. Passive retention posts depend upon their close proximity to the dentin walls, but by adherence of the cementing medium. Good examples are cast posts, smooth tapered posts, serrated parallel posts, and variations of these. For example, para-post is a serrated, vented, prefabricated parallel post.

Active retention posts depend primarily on engaging the dentin. These have threads that either screw into the dentin, such as a wood screw, e.g. flexi-post; or that fit into threaded channels "tapped" into dentin much like a bolt, e.g. Kurer anchor. Retention by cementation is secondary to the engagement of the dentin.

I. PASSIVE RETENTION POSTS

As stated above, passive retention posts fit the canal or the channel in the canal specially prepared for them. With gross flaring of the canal, only a cast post property reflects the canal's shape and size. Channels prepared in ovoid canals find the post approximating the walls on only two sides. In a round canal, a proper channel may be prepared so the post will fit overall, and this would be the maximum mechanical retention one might expect. So primarily, passive post retention depends on cementation, there being a layer of cement between post and canal wall or a "sea of cement" in which the post is buried.

a. Tapered, Smooth-Sided Posts

The oldest and most widely used design is the tapered, smooth-sided, cemented post. Systems employing this configuration are the Kerr Endopost, and the Mooser post and all custom-cast posts. There is also a tapered - knurled post, the Ellman Nu-Bond. The wide usage of tapered posts may be attributed to their ease of utilization since the tapered form is the natural shape of an endodontic canal.

Post Retention. The tapered, smooth-sided, cemented post is the least retentive of all post designs. By configurational similarities, the same conclusions can be drawn for the custom-cast post. It is suggested that these designs be used in teeth not subjected to high functional or parafunctional loads and where other designs are contraindicated.

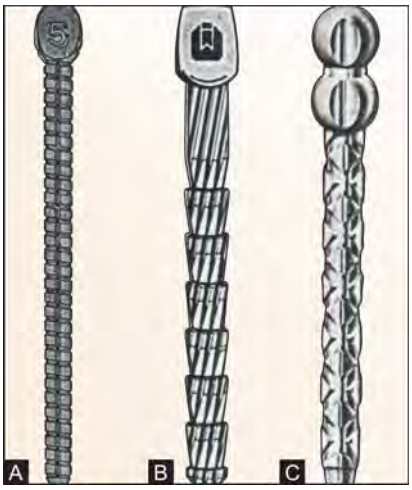
In spite of laboratory findings, Weine believes the tapered smooth post has received a "bad press." He reported on 138 endodontically treated teeth that had been restored for at least 10 years with tapered smooth posts, cores with complete or 7/8 cast ferrules, and an onlay or cast precious metal crown. There were 9 failures in 138 teeth (6.5%)-3 restorative, 2 endodontic, 2 root fractures, and 2 periodontal. Weine claims that, when used properly, tapered smooth posts have no retentive problems.

Stress from Installation. Because of their taper, these posts are self-venting and easily cemented. Hydrostatic pressures do not develop during cementation because a taper does not act as a piston. The only evidence of stress is seen where the tapered post contacts irregularities produced in the canal wall during preparation of the post channel.

Stress from Mastication. Tapered-smooth posts are wedges and, as such, exert a wedging pressure upon roots during function. With other factors being equal, the propensity for root fracture from tapered posts is cause for concern. The wedging effect of a tapered post is related to the flare of the post channel: the greater the flare, the higher the wedging effect. It would seem prudent, therefore, to minimize the flaring of the canal during both the cleaning and shaping, and post space preparation procedures.

b. Parallel-sided Posts

Posts with parallel sides, when cemented into prepared parallel channels, provide much greater retention with less stress than tapered posts Examples are Whaledent-Posts, the Boston Post and the Parkell Parallel Post. The parallel and serrated Para-Post is the most widely used.



Figs 17.16A to C: A. Para-post, B. Para-post Plus, C. Unity Post

i. The Para-Post System (Figs 17.16A to C)

Whaledent has introduced three post designs: the original Para-Post, Para-Post Plus, and the Unity System. All are passive, parallel, vented posts made of either stainless steel or titanium. Cement retention is gained by horizontal serrations on the Para-Post, spiral flutes and grooves on Para-Post Plus, and a raised diamond pattern on the Unity Post. Any cementing medium is acceptable.

Post retention: The parallel-sided, serrated, vented post provides substantially greater retention than the smooth tapered design. Consequently, these posts can be effectively employed in situations where higher applied forces are expected. As one might expect, the Para-posts being cement dependent are not as retentive as the active-threaded posts, although a study in Toronto found no statistically significant difference in retention among Para-Post, Flexi-Post, and Boston Post. At Oregon, however, it was reported that active Flexi-Posts were over twice as retentive as passive Para-Posts.

Stress from installation: The Para-Post has a vertical groove cut the length of its serrations, allowing axial venting. This design allows cement to escape and thus avoids the stresses that may be induced in the dentin by other cemented parallel posts.

Stress from mastication: Overall, the parallel-sided, serrated Para-Post has been shown to provide the most equitable distribution of masticatory forces of all available post designs. Above all, it avoids the wedging effect of tapered posts. The transfer of occlusal forces of the tooth occurs via the cement layer, which serves to buffer the forces. Together, these two factors result in a uniform distribution of stresses in the supporting tooth.

Burgess found the Para-Post slightly less resistant than Flexi-Post but a good deal less resistant than V Lock, another active post. In resistance to torsional (torque) forces, Para-Post was a good deal less resistant, as one might expect. The developers of Flexi-Post reported no failures to cyclic fatigue testing of either the Para-Post or Flexi-Post after 2 million flexures.

All in all, though the Para-Post is not as retentive as active posts but is a good deal less stressful in placement. It also withstands compressive and fatigue forces as well as the dentin-engaging posts.

ii. The Boston Post System

In physical design, the Boston Post very much resembles a Para-Post without the vertical venting channel. It is a passive dowel, 99.6 percent titanium, with horizontal non-engaging serrations. It is almost wholly dependent on its special "cementing" medium for retention. In 1993, the Boston post configuration was redesigned with deeper grooves and an etched and roughened surface to allow greater retention.

Post retention: Goldman and Nathanson developed the Boston Post at Tufts following their search for better dowel retention without the stress induced by dentin-engaging posts. They decided the best retention would be the dentin itself. Freed of the smear layer, the open dentinal tubules offered a labyrinth of interlocking space into which a cementing medium might flow. They finally settled on a dentinal wall bath of EDTA and NaOCl-2.5 ml of each irrigated into the canal. The first wash is with 17 percent EDTA (7.0 pH) to chelate away the inorganic dentin, followed by 5.25 percent NaOCl to remove the organic dentin. This totally removes the smear layer but leaves the peritubular dentin in place.

The Tufts group also discovered that an unfilled BisGMA resin was the best "cementing" medium, better than zinc phosphate or polycarboxylate cements, or a filled resin, Standlee and Caputo

subsequently found unfilled resin to be 10 times more retentive than filled resin. Gelfand spoke of the retentive qualities gained by removing the smear layer. Using an unfilled resin, he found no statistical difference in retention between the passive Boston Post and Para-Post, and the Flexi-Post that engages the dentin.

Nathanson, one of the developers of the Boston Post system, found that the tensile strength required for removing a Boston Post was somewhat greater than a Flexi-Post cemented with EDS composite resin, and twice as retentive as Para-Posts cemented with zinc phosphate cement. Removing the smear layer greatly enhances retention. Standlee and Caputo showed greater retention of passive posts, no matter the cementing medium, when the smear layer was removed.

Stress from installation: As with the Para-Post, there is virtually no installation stress imposed by the Boston Post.

Stress from mastication: No information is available about compressive or torsional forces applied to crowns restored with the Boston Post system. One questions the advisability or necessity, however, of producing the post from titanium, which has only half the stiffness of stainless steel.

iii. Parkell Parallel Post System (Fig. 17.17)

This is stainless steel, passive, vented, serrated post with an anti-rotational lock that fits into a "seat" prepared in the root surface. There are no reports on the safety and efficacy of this system. Its popularity might be related to plastic core formers that come with the posts. These allow the dentist to build up an immediate composite resin crown core. Cementing the post and core with 4-META adhesive, bonding both to the tooth surface, might allow for the lack of a ferrule. The Parkell Post also comes in a plastic burn-out pattern for a cast version. This model would encourage root preparation to receive a ferrule in the core casting.

Fig. 17.17: Parkell parallel post system

iv. Parallel-sided Posts with Tapered Apical Ends

These posts, designed to provide the greater retention of parallel posts, yet better conform to the tapered apical portion of the canal, come in 2 variations. One, the Degussa, is completely smooth-sided. The straight and tapered portions are about equal in length. The second variation is the Unitek BCH System with lower frequency of serrations along the parallel sides and a smooth apical taper of about 2 mm. The BCH post also has a larger coronal portion to provide retention for core build-up materials.

Post retention: Parallel posts with tapered ends have a lower retention potential than regular parallel posts of comparable length and diameter.

Stress from installation: Parallel-sided posts with tapered ends, when cemented in place produce little or no installation stress.

Stress from mastication: All the cemented, parallel-sided posts with tapered ends produce a definite wedging effect in the area of the apical taper. These posts will, therefore, be more apt to cause root fracture than parallel-sided posts of comparable length and diameter.

II. ACTIVE RETENTION POSTS

As previously defined, active retention posts depend primarily on external threads that engage the dentin for retention. Cementation is necessary but secondary.

There are two types of these posts: (a) Those with self-threading screws that engage the dentin walls of a prepared post channel, cutting their own counter-threads, are best epitomized by the Dentatus post, the Radix Anchor Post, and the Flexi-Post. (b) The type that "bolts" into counterthreads, pretapped in the dentin, is the Kurer Anchor post.

a. Posts with Self-Threading Screws

Tapered Dentatus (Fig. 17.18)

One of the earliest of the self-threading posts is the Dentatus. Although it is more retentive than passive/cemented posts, it is also more dangerous.

Post retention: While it is true that the tapered Dentatus screw post is more retentive, it is also true that it gains its retention by spreading the dentin as it self-threads. Loss of the crown is often the first indication the root has split.

Stress from installation: The self-threading tapered screw produces the greatest stress by far when installed in the root. Not only is it a wedge, but it sets up fracture lines as it "cuts" and spreads its way into the dentin. Stress is highest and most concentrated at lengths under 5 mm when the Dentatus acts as a tapered wedge. Even when it is "backed off" one half turn, little reduction in stress concentration is seen.

Stress from mastication: The wedge configuration of the screw design is accentuated under load when occlusal forces are added to the installation forces described above. Self-threading tapered screws possess the worst installation and occlusal stress-producing characteristics of all existing designs.

Tapered Flexi-Post (Fig. 17.19)

A variation of the self-threading screw is the Flexi-Post, which has become one of the most popular post systems. Flexi-Post is a prefabricated, split-shank, parallel-sided, threaded post that reportedly absorbs the stresses of insertion (by gradually closing during placement) while providing maximum retention. As the apical half "collapses", it becomes a tapered post.

Post retention: As a self-threading screw, the Flexi-Post gains its significant retention by its threads cutting into the dentin 0.1 mm to 0.2 mm. The channel to receive the post is prepared by a drill sized slightly larger than the diameter of the shaft of the post. The blades (threads) extend beyond the shaft by 0.2 mm and engage into the dentin. The manufacturers recommend that further retention be gained by cementing the post with a titanium-reinforced composite, Flexi-Flow. The posts also come in other configurations, Flexi-Flange and Flexi-Post Overdenture Attachment.

There is no question that Flexi-Post enjoys a retention reputation. Burns reported Flexi-Post "significantly more retentive than the Para-Post". At Texas, San Antonio, Flexi-Posts provided the greatest resistance to torsion and tensile loading (pulling them out). The developers of Flexi-Post reported Flexi-Post more retentive than Para-Post, Filpost or V-Lock posts. They further commented that retention failures are often due to "the inherent weakness and brittleness of the cement." Constant crown micromovement leads to decementation (brittle cements tend to disintegrate under continued cyclic loading). The developers also reported that Flexi-Posts may be shortened by as much as 4 mm (but not 5 mm) without reducing their retention. Standlee and Caputo showed that Flexi-

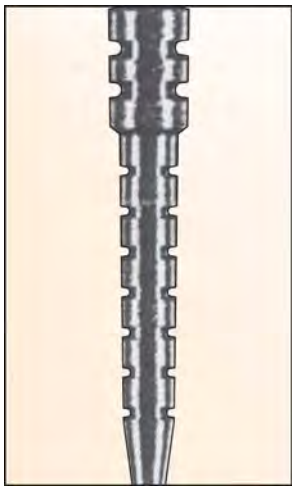


Fig. 17.18: Dentatus Post

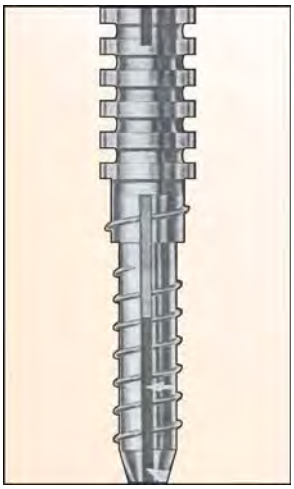


Fig. 17.19: Flexi-Post

posts were more retentive than Para-posts and Radix Anchor posts, but a good deal less retentive than the Kurer Anchor Posts.

Stress from installation: Because it is an active-type post, that is, self-threading into the dentin, Flexi-post must exert some stress when it is installed. It is first "screwed" into the prepared canal with a tiny "wrench", then removed counterclockwise, to be reinserted with cement into the same dentin threaded grooves.

The manufacturer claims that because the apical half of the post is split, it collapses inwardly, thus reducing the strains that would otherwise be produced were it a solid screw. This appears to be true, according to the University of Washington workers, the insertion strains were twice as high for the upper tier of the Flexi-Post (the solid shaft, compared to the lower tier), the split shaft. At UCLA, much the same was found, that the Flexi-Post created "high stress levels in the coronal half of the dowel channel". The Washington group found, however, that compared to other "active" posts, the Flexi-Post induced the least insertion strains.

Stress from mastication: Using a fatigue-testing apparatus that simulates the forces of mastication and swallowing, the Flexi-Post developers compared the cyclic-fatigue results from 6 endodontic post systems. After 2 million fatigue-cycles there were no failures in the Flexi-Post or Para-post systems against early failure with the Cytco posts and 60 percent failure with the V-Lock posts.

b. Self-Threading Parallel-Threaded Posts

Two principal self-threading parallel posts are currently popular, the V-Lock and the Radix Anchor System. Both have low frequency sharp threads, and both are vented to reduce hydraulic cementation stress. They differ in the length of the threads down the shaft.

Parallel V-Lock Drill and Post System

The widely separated "micro-threads" of the V-Lock post extend 0.5 mm from the shaft and continue its full length. V-Lock posts are supplied with precise drills that prepare a parallel-walled canal just slightly larger than the post shaft. They can be cemented with any cement or adhesive.

Post retention: An Oregon study found that V-Lock posts were less than half as retentive (112 lb) as Flexi-Posts (270 lb) and quite comparable to passive Para-Posts (106 lb). Another study also found V-Lock retention comparable to that of Para-Posts, and yet another study placed V-Lock posts about halfway between Paraposts and Flexi-Posts.

Stress from installation: At Creighton, workers evaluated the possibility of cracks or fractures arising from the insertion of V-Lock posts and found none. At Washington, V-Lock posts were somewhat more stressful than Flexi-Posts when threaded and cemented, and in the US Air Force, it was found that V-Lock posts caused incomplete root fractures 10 percent of the time, just as did Flexi-Post or simply filling the canal by lateral condensation.

Stress from mastication: It was reported that V-Lock posts were the most resistant to compressive loading, somewhat more than Flexi-Post or Para-Post. In resistance to torsional loading tests, V-Lock posts fell about midway between Para-Posts and Flexi-Posts. Fatigue tests, however, found that 60 percent of the V-Lock posts failed before the fatigue cycle was completed (2 million repetitions).

Parallel Radix Anchor System (Fig. 17.20)

Like the other active-retentive posts, Radix Anchor posts gain their primary retention by self-cutting

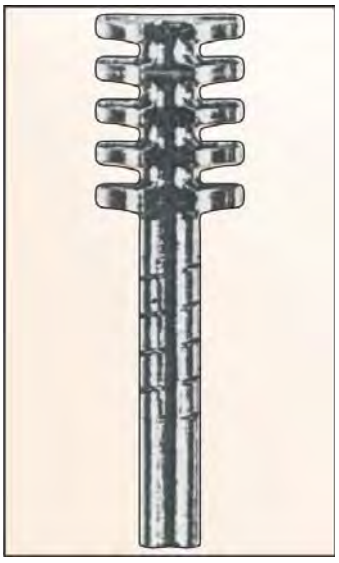


Fig. 17.20: Parallel Radix Anchor system

counter threads in the dentin. As a parallel post, the Radix differs from the V-Lock post by the number of its threads, which are sharp low-frequency helical blades that extend only partly down the shaft. It is vertically vented. The Radix post is designed to fit snugly in a channel prepared for it in the root. It can be cemented with any cement, but composite resin, also used to buildup the core, seems preferred.

Post retention: Because of the limited number of threads, the Radix Anchor has less retention than other actively retained posts. Moreover, if the canal is ovoid or too flaring, the blades never contact dentin. In that case, it has hardly more retention in cement than a smooth post.

Stress from installation: If the post is fully seated (fully engages the bevel produced by the twist drill at the channel apex), severe stress levels will ensure. To obviate apical stress with Radix posts, they can be counter-rotated one half-turn after resistance is detected. Although this frees the post from the apical bevel, it does not loosen the post if physical contact is still present between post threads and the dentin. Counter-rotation also frees the coronal seat from impinging on the root face. A fully seated Radix Anchor induces severe stress due to surface irregularities of the root face and the non-perpendicular alignment of the post and coronal dentin.

Perhaps the most critical aspect of parallel-sided threaded design is the initial threading insertion and the later cementation. Following channel preparation, the post is carefully threaded into the dentin. It is then backed out to be returned for final cementation. In the initial threading operation, Ross, Nicholls, and Harrington noted that the Radix Anchor generated more apical root strains than any other post: 3428 micro-inches/inch of strain vs. 782 for the V-Lock, and 344 for the Flexi-Post. Apical strains during cementation were nearly as bad: 1743 for the Radix, 473 for the V-Lock, and 316 for the Flexi-Post. The authors felt that the sharpness of the threads and the difficulty of perfectly aligning the unthreaded apical end of the post with the prepared channel both played a significant role in strain production.

Stress from mastication: The Radix Anchor post generates greater stress under oblique compressive forces than the Kurer post. The main load transfer takes place between the threads and the dentin. Since there are so few threads on the Radix Anchor, the localized stress concentrations are raised under load because of the lowered surface contact.

c. Parallel Threaded Posts with Pre-Tapped Channels

The Kurer Anchor posts are the only posts on the market that fit into pre-tapped counter-threads in the dentin. As such, they are the most retentive posts available, no matter what the cementing medium. Kurer anchor posts are parallel in design with no vertical vent. They have rounded high-frequency threads that fit into counterthreads "tapped" into the dentin with a manual thread cutter. They come in a number of configurations (Fig. 17.21).

Another unique feature of the Kurer Anchor is the Kurer Root Facer (Fig. 17.22) that prepares a flat seat in the root face into which the coronal portion is to fit perfectly. This obviates the problem of Radix Anchor (fitting against an uneven root surface).

Post retention: Parallel-sided, threaded posts, cemented into tapped channels, are superior in retention to all other post designs. The Kurer Anchor post is more retentive than the Radix Anchor simply because of the higher frequency of threads. The Kurer Anchor, cemented with zinc phosphate was found to be 24 percent more retentive than the Flexi-Post, cemented the same and 35 percent more retentive than the Radix Anchor. In another report, Kurer Posts were found to

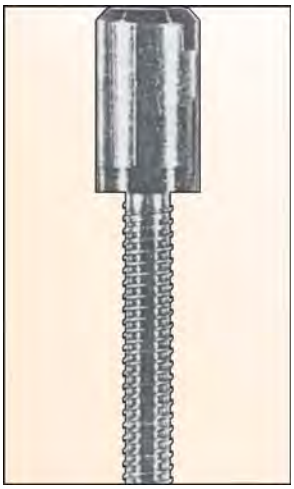


Fig. 17.21: Kurer Post

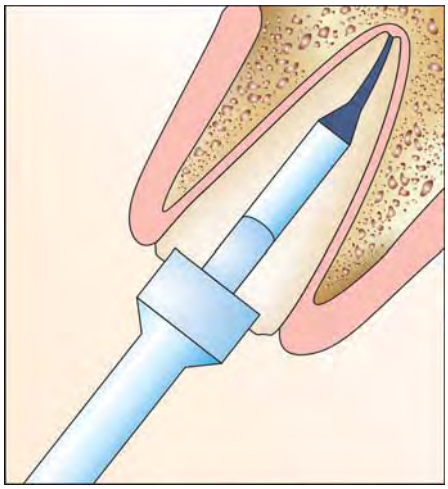


Fig. 17.22: Kurer Root-Facer used to "mill" a flat foundation in root preparation for crown post head

be more retentive than (in descending order of retentive ability) Brasseler V-Lock, Radix Anchor, and Flexi-Posts.

Because of its high retentive capability, the Kurer Post is favored when very high loads must be supported: partial denture and overdenture attachment abutments, long span bridges, etc. This post is also very useful when only short embedment depths are possible because of root length and shape.

Kurer posts have less value in widely flared canals that are too broad to be properly tapped with retentive threads. On the other hand, if only 2 or 3 mm can be threaded, the Kurer post will undoubtedly be more retentive to other posts.

Stress from installation: Kurer posts produce severe apical stress levels if the apex of the post fully engages the bevel produced by the twist drill at the channel apex. In that it is similar to the Radix Anchor. Trimming the post length short of the apical bevel in the canal may obviate this. When cemented, it should be fully seated with the end of the threaded shank just short of the tapered part of the channel. The coronal seat in the root-facer preparation should be just touching, not screwed down so tightly it produces strains.

At Washington, using strain gauges on the outside of the root, the researchers found that tapping the dentin and inserting the Kurer post produces strains, more than Flexi-Post and V-Lock, but not as much as the Radix Anchor. In cementing, however, the Kurer Anchor produced more strains than the Radix Anchor: 1976 microinches/inch vs. 1743 for the Radix. The absence of a vent in the post's design may play a key role in the magnitude of the observed strains. With each turn of the screw, the strains would rise, then dissipate, which provides the clue to how slowly these posts should be cemented.

As the Washington study proved, tapping the dentin and trial insertion of Kurer posts are critical in strain production. They were very careful to constantly remove the thread cutter to clean it. If the vents of the tapping instrument are allowed to clog with debris, or the taps are rotated forcefully, greatly increased stress will occur. Thorough irrigation and smear layer removal should also follow the tapping procedure.

Stress from mastication: When Kurer posts are cemented into their tapped channels, their buffering effect is less pronounced than it is for other designs. The main load transfer takes place between the threads and the dentin. The high-frequency threads of the Kurer design lower the localized stress concentrations under load because of the increased surface contact. In this, Kurer Posts differ from the low-frequency thread Radix posts.

CLINICAL TECHNIQUE

Non-metallic Posts

Fiber Reinforced Posts

Contents and mechanical properties of some fiber reinforced foot canal posts

Post	Contents	Flexural Modulus (GPa)	Flexural Strength (MPa)
Composipost (RTD)	Carbon fiber 64%, epoxy	145	1,500
Light-post (RTD)	Quartz fiber 60%, epoxy	46	1,400
Luscent (Dentatus)	Quartz fiber 70%, polyester	40	890
Para Post Fiber White (Coltene/Whaledent)	Glass fiber 42%, filler 29% metharylate resin 29%	29	990
Postec (Ivolclar Vivadent)	Glass fiber 61.6%, urethane dimethacryalate 18.3% triethylene glycoldimethacrylate 7.6%	45	1,390

Carbon-fiber Posts (Qualtrough and Mannocci)

Carbon-fiber reinforced posts consist of fibers of carbon surrounded by a matrix of polymer resin, usually an epoxy resin. Their main proposed advantage is that they are more flexible than metal posts and have approximately the same modulus of elasticity as dentin. The main disadvantages of the carbon fiber post are its dark color and radiolucent appearance in a radiograph. More recent variations are zirconium coated posts (Aestheti Plus, Bisco) which are white in color. They are relatively easy to remove by drilling through the middle of the post with an ultrasonic or rotary instrument. The orientation of the fibers help keep the instrument properly aligned.

Adhesive systems form weaker bonds to carbon-fiber posts than to stainless steel and titanium but stronger than to zirconium dioxide. The water sorption and solubility also vary with brand and homogeneity of polymer matrix and may affect the hydrolytic stability of the composite structure. In one study, water immersion was found to reduce the strength and stiffness to about 70-60 percent of the dry values. These posts also exhibited a significant decrease in strength after thermocycling. This has been attributed to degradation of the fibers or the matrix and to difference in thermal expansion coefficients between the two.

Clinically, carbon-fiber posts have been used successfully. Studies have shown low failure rates. Root fractures, when they occur, tend to be of favorable types when compared with metal posts that cause irreparable root fractures. Studies show that these post systems fail under load instead of causing root fracture when compared with metal posts, which generally cause root fracture.

Glass Fiber and Other Fiber Reinforced Posts (Fig. 17.23)

Carbon-fiber posts are black in color and do not lend themselves to esthetic restorations with all-ceramic units. This led to the introduction of silica-fiber posts that are translucent and tooth colored. These posts are glass-fiber (S glass) and quartz-fiber posts. Another type of fiber used in posts is bondable ribbon woven polyethylene (Ribbond), which can also be used with composite to create an entirely custom made cast dowel and integrated core. This bondable ribbon post and core was shown to have significantly lower fracture resistance than carbon fiber posts, metal posts and custom cast posts.

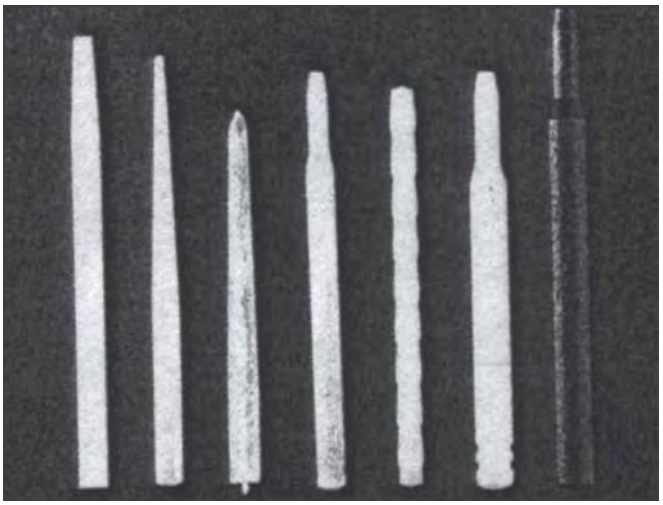


Fig. 17.23: Nonmetallic posts (left to right) Cosmopost (Ivoclar), Cerapost (Brasseler), Luscent Anchor (Dentatus), Light-post (Bisco), FibreKor Post (Jeneric/Pentron), Aestheti-Plus (Bisco)

ADVANTAGES

1. Less chances of fracture.
2. Forces are equally distributed (not concentrated at the apex as in metal)
3. Suitable for esthetic final restorations like all ceramic restorations as light passes through the ceramic crown and the composite restoration at the same wavelength leading to better esthetics as compared to other post-core materials and metal ceramics.

Ceramic and Zirconium Posts (Schwartz and Robbins)

Another esthetic alternative to metal and carbon fiber posts are the ceramic posts. In 1994, Sandhaus and Pasche introduced the prefabricated zirconia endodontic post. These posts work clinically, but have several disadvantages:

- As a group, they tend to be weaker than metal posts, so a thicker post is necessary, which requires removal of additional radicular tooth structure.
- Though the all-zirconium post is reported to have a modulus of elasticity higher than that of stainless steel, its fracture resistance is low.

- Zirconium posts cannot be etched with hydrofluoric acid; therefore, it is not possible to bond a composite core material to the post, making core retention a problem. To overcome this, a technique has been described whereby a leucite-reinforced ceramic core material (Empress) is pressed onto the zirconium post.
- Retrieval of zirconium and other ceramic posts is very difficult if endodontic retreatment is necessary or if the post fractures. Some ceramic materials can be removed by grinding away the remaining post material with a bur, but this is a tedious and dangerous procedure. It is impossible to grind away a zirconium post from a canal placement. For these reasons, ceramic and zirconium posts should be avoided.

All-Ceramic Post and Core (Koutayas and Kern)

With the introduction of the current all-ceramic systems, the use of all-ceramic posts and cores was suggested as an alternative to solve the esthetic problems that metal posts and cores exhibit. In 1989, Kwiatkowski and Geller described the clinical application of glass-ceramic posts and cores and in 1991, Kern and Knode introduced posts and cores made of glass infiltrated aluminium oxide ceramic. In 1995, Pissis proposed a technique for the fabrication of a post and core and a crown as a single component made out of glass-ceramic material. In 1994 and 1995, Sandhaus and Pasche and others introduced prefabricated zirconia ceramic endodontic posts to restorative dentistry. They also suggested use of zirconia ceramic for the fabrication of core buildup and final restoration.

The major advantage of an all-ceramic post and core is its dentin like shade. The positive contribution of the dentin shade ceramic core is related to the deeper diffusion and absorption of the transmitted light in the ceramic core mass. An all-ceramic restoration transmits a certain percentage of the incident light to the ceramic core and post on which it had been placed. Thus, with all ceramic posts and cores, the color of the final restoration will be derived from an internal shade similar to the optical behavior of natural teeth. Relatively low fracture strength and toughness are the main obstacles for an extended use of conventional dental ceramics as post and core materials. High toughness ceramics, such as the glass-infiltrated alumina (In-ceram) and the dense-sintered alumina ceramic (Procera), show a 3-6 times higher flexural strength and fracture toughness than do conventional feldspathic and glass ceramics. Contemporary zirconia powder technology contributes to the fabrications of new biocompatible ceramic materials with improved mechanical properties, i.e. further increased flexural strength and fracture toughness. Therefore, zirconium oxide ceramic seems to be a very promising material for the fabrication of all ceramic posts and cores.

CLINICAL TECHNIQUES

Post Selection

The post system to be used depends on:
1. Root morphology.
2. Remaining coronal tooth structure.
3. Occlusal forces.

Root Morphology

- If the root narrows considerably in the apical one-third (e.g. maxillary first premolars and mandibular central and lateral incisors), the use of a parallel post may come dangerously close to perforating the lateral surface of the root. Even if perforation does not occur, it will weaken the root. The alternative is to use a tapered post or a parallel post of shorter length. Their drawbacks are that the tapered post induces wedging forces, whereas the short parallel post provides lesser retention and also the occlusal forces are distributed over a shorter root length.
- Oval or ribbon-shaped canals cannot be prepared easily to receive circular, parallel post. In these situations a custom post formed to the shape of the canal conserves tooth structure and involves less preparation in the apical region of the root.
- If it is possible to prepare a cylindrical channel equal to or longer than the clinical crown of the tooth, a parallel cemented post in combinations with coronal core will best fulfill requirements.
- Where esthetics is a concern, tooth colored glass fiber or ceramic posts should be used.

Remaining Coronal Tooth Structure

As already discussed, the amount of remaining tooth structure will determine the need for post and core restoration.

Occlusal Forces

Occlusal forces on individual teeth are influenced by:

- Tooth type and position—Molars have high forces acting on them than for incisors and premolars.
- Presence or absence of adjacent teeth—Occlusal forces dissipated to adjacent teeth via proximal contacts. Absence of adjacent teeth increases the amount of forces acting on the individual teeth.
- The functions the tooth must serve, e.g. RPD or FPD amount. Here the amount of forces acting on the individual tooth is increased.
- Patient's occlusal habits e.g. bruxism.

The higher the occlusal forces, the greater the retention needed. This can be achieved by using parallel-sided posts. In multirooted teeth, additional posts can be used to increase retention.

Removal of the Endodontic Filling Material

It is recommended that the root canal system should first be completely obturated and then space made for a post. This will ensure that the lateral canals are sealed. A post cannot be placed if the canal is filled with a full length silver point, so these must be removed and the tooth re-treated with gutta percha.

The two commonly used methods for gutta-percha removal are:

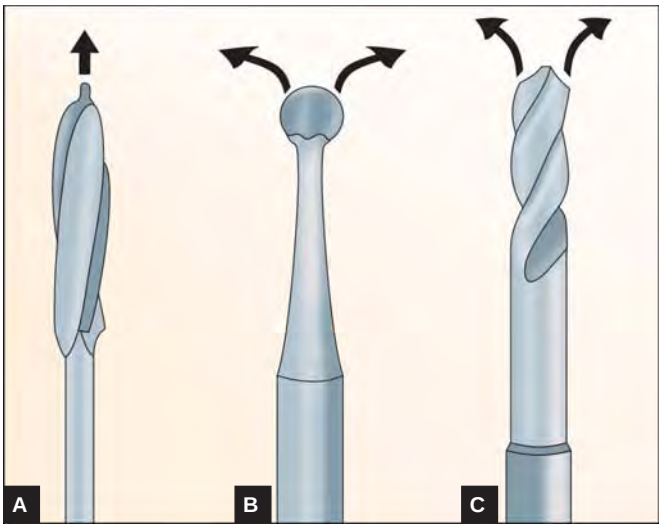
1. With a heated endodontic plugger.
2. With a rotary instrument.

Though previously it was thought that rotary instruments would disturb the apical seal, recent research has shown that both methods can be safely used to remove gutta-percha without disturbing the apical seal when 5 mm of gutta-percha is retained apically (Ingle).

Controversy also existed regarding the timing of removal of gutta-percha after endodontic treatment. It was believed that removal should be delayed by 1 week, as intermediate removal should disturb the apical seal. Now, it has been shown that adequately condensed gutta-percha can be safely removed immediately after endodontic treatment. If doubt exists about the endodontic treatment, removal should be done after 1 week.

Removal with Rotary Instruments (Fig. 17.24)

Gutta-percha can be removed with GG drills, Peeso reamers, Parapost-drills and other commercially available burs. When rotary instruments like burs or drills are used, it should be ensured that the instrument follows the gutta-percha and does not engage the dentin otherwise perforation will occur. For this reason GG drills and Peeso reamers (A) are preferred as their non-cutting tips keep them centered on the gutta-percha (the path of least resistance).



Figs 17.24A to C: Instruments For Post Space Preparation: Peeso reamer, Round bur, Drill

Technique (Fig. 17.25)

1. Choose a Peeso reamer slightly narrower than the canal.
2. The depth of insertion is determined by superimposing the Peeso reamer over the radio-

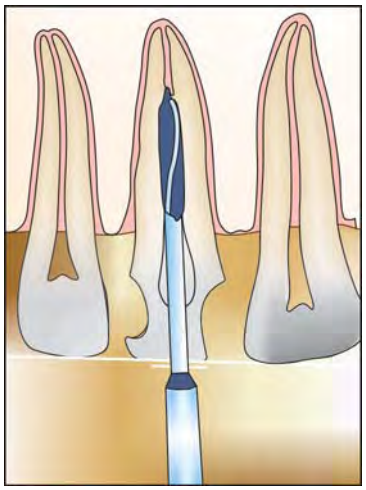


Fig. 17.25: Post- space preparation with Peeso-reamer

graph of the tooth being restored. Set the stopper at the level of incisal edge of adjacent teeth.
3. Carefully remove the gutta-percha and avoid cutting the root dentin. Often only a part of the root canal fill need be removed with a rotary instrument, and the remainder can be removed with the heated condenser.
4. Once removal reaches the appropriate depth, shape the canal as needed.

Removal with a Heated Endodontic Condenser

In this method a heated endodontic plugger or an electronic device is used to remove the gutta-percha. This method is commonly used when gutta-percha is to be removed right after obturation as there are minimal chances of disturbing the apical seal.

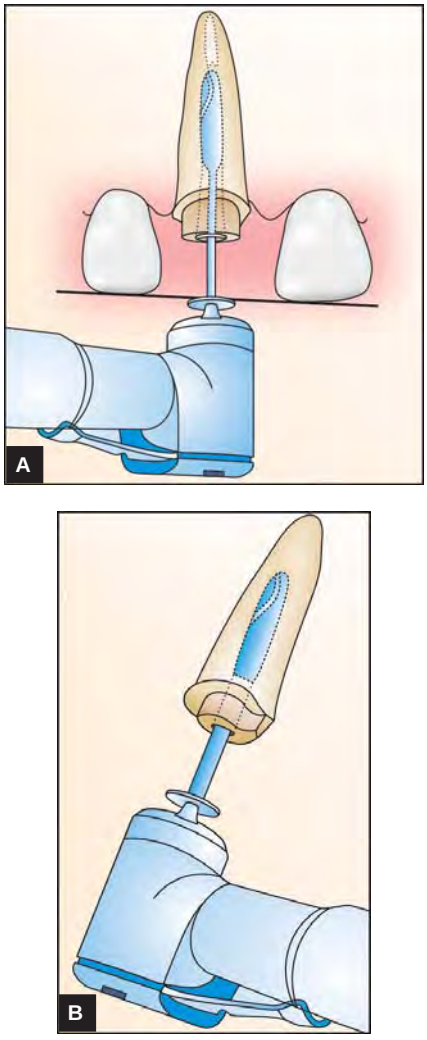
Technique

1. Before removing gutta-percha, calculate the appropriate length of the post. As a guide, the post length should be equal to the height of the anatomic crown or two-thirds the length of the root, whichever is greater, but 5 mm of apical gutta-percha should be left. In short teeth, compromises must be made. An absolute minimum of 3 mm of apical fill is needed. If this cannot be achieved without having a very short post, then prognosis of the tooth is impaired.
2. Avoid the apical 5 mm if possible as curvatures and lateral canals are found in this segment. The instrument is gauged for length against a preoperative radiograph and the stopper is set at the level of incisal edge of adjacent teeth.
3. Apply rubber dam to prevent aspiration of instrument.
4. Select an endodontic condenser large enough to hold heat well but not so large that it binds against the canal walls.
5. The instrument is heated till it is red hot, inserted into the gutta-percha and is quickly withdrawn. This sears off the gutta-percha. The condenser if kept for a longer time or is not heated well, the gutta-percha will stick to the instrument resulting in its being pulled out when the condenser is withdrawn, thus disturbing the endodontic seal.
6. If the gutta-percha is old and has lost its thermoplasticity, use a rotary instrument.

Enlargement of the Canal (Fig. 17.26)

This is accomplished with instruments like Peeso reamers or a low-speed drill. The purpose is to remove undercuts and prepare the canal to receive an appropriately sized post without excessively enlarging the canal. It has been recommended that the post be no more than one-third the diameter of the root with the root and walls at least 1mm thick. Thus, knowledge of average root dimensions is important in addition to root canal shapes.

Before starting canal preparation, remove any existing restorations, caries, bases and thin or unsupported walls of tooth structure preserving as much tooth structure as possible.



Figs 17.26A and B: Post space preparation with Peeso-reamers and finishing with specific drill

For Pre-fabricated Posts

1. Set the stopper on the instrument to the predetermined length. Enlarge the canal one or two sizes with a drill, endodontic file or reamer that matches the configuration of the post. When Peeso reamers are used (A), the canal is enlarged to a diameter slightly smaller than that of the specific instrument (e.g. Para-post Drill) required for the system being used. Final preparation is then done with that instrument (B). In case of a threaded post, a tap (to make threads in the dentin) follows the appropriate drill, unless self-threading screws are being used.
2. Enlarging the canal in 0.2 mm increments diminishes the possibility of the instrument straying from the canal. Conventional drills used without any prior enlargement of the canal are more prone to stray from the original canal pathway than Peeso reamers.
3. Be careful not to remove more dentin at the apical extent of the post space. Radiographs are not normally required, provided careful measurement techniques have been followed (Fig. 17.27).
4. To provide anti-rotational resistance, a pin may be used. Drill one or two 0.6 mm pin holes to a depth of 2 mm, in the area of the greatest bulk between the canal and the periphery of the tooth (usually on lingual side).

For Custom-made Posts

Often very little preparation will be needed for a custom-made post. However, undercuts within the canal should be removed and some additional spacing is usually necessary.

1. Set the stopper on the instrument to the predetermined length.
2. Gradually enlarge the canal (in 0.2 mm increments) to the size that has been determined for that tooth. As already mentioned, it should not be greater than one-third the diameter of the root at the CEJ (A) and there should be a minimum thickness of 1.0 mm of tooth structure around the post at mid-root and beyond (B) (Fig. 17.28).
3. If anti-rotational resistance is required use a no. 170 bur to make a key way or groove in the orifice of the canal. Place it in the area of greatest bulk. It should be cut to the depth of the bur (approx. 0.6 mm) and up the canal to the length of the cutting blades of the bur (approx. 4 mm) (Fig. 17.29). On a

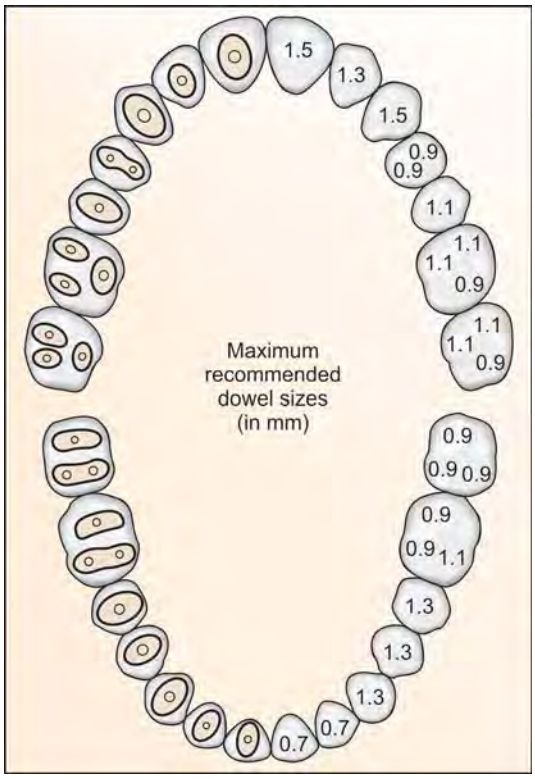


Fig. 17.27: The outlines of the roots and the posts are shown superimposed on the occlusal surfaces of the teeth on the left.The recommended post diameters are shown on the right.(From Shillingburg, 3rd ed.)

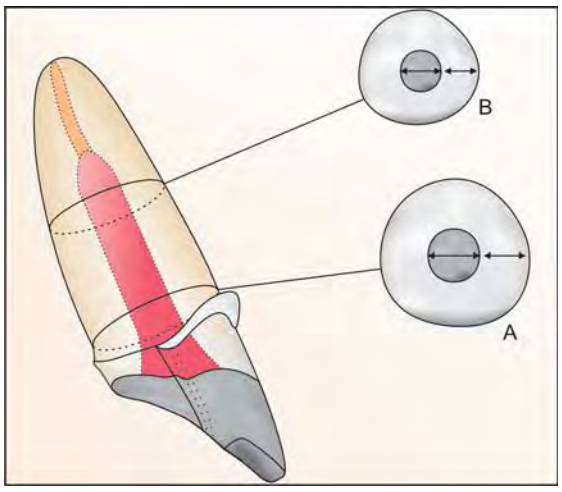


Fig. 17.28: Guidelines for post space diameter

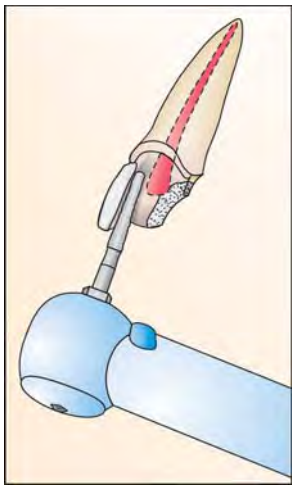


Fig. 17.29: Antirotational groove

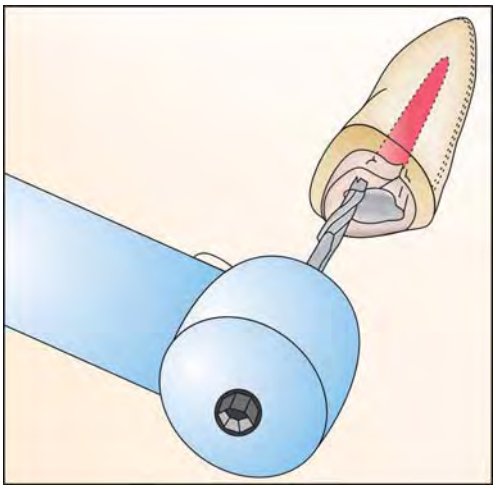


Fig. 17.30: Coronal tooth preparation

premolar and molar, the second canal serves the anti-rotational function.

Preparation of Coronal Tooth Structure

After the post space has been prepared, the coronal tooth structure is reduced for the extracoronal restoration. Anterior teeth are restored with metal-ceramic crown or when esthetic posts and cores used, with an all-ceramic restoration. All-metal crowns are generally given for posteriors.

1. Ignore any missing tooth structure and prepare the remaining tooth as though it was undamaged (Fig. 17.30).
2. The facial surface (in anteriors) should be adequately reduced for good esthetics.
3. Remove all undercuts that will prevent removal of pattern. This is not needed with direct core buildups.
4. Preserve as much tooth structure as possible.
5. Prepare the finish line at least 2 mm gingival to the core. This establishes the ferrule. For custom-made post and core restorations, place a contra-bevel with a flame-shaped diamond at the junction of the core and tooth structure (Fig. 17.31). The bevel provides a metal collar around the occlusal circumference of the preparation (in addition to the Ferrule) in bracing the tooth against fracture. It also provides a vertical stop to prevent over-seating and wedging effect of the post.
6. Complete the preparations by eliminating sharp angles and establishing a smooth finish line.

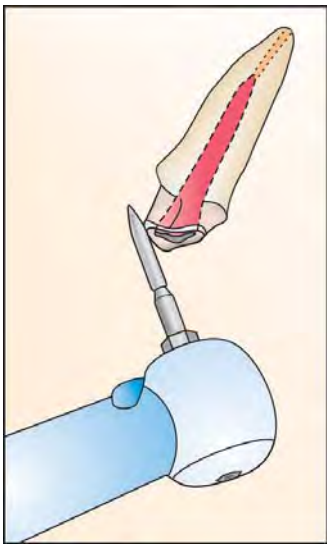


Fig. 17.31: Contrabevel

POST FABRICATION

Prefabricated Posts

These have to be selected to match the dimensions of the canal. They must be seated till full depth. Any discrepancy between the coronal part of post and canal wall can be filled with core material during the build up of core.

To shorten the length of the post:

- Do it at the apical end if the post has a special shape to the head (for retention of core).
- If the post has a specially shaped apical tip (e.g. tapered end in a parallel post like BCH post), do any needed shortening at the coronal end. At least

2-3 mm of the post should be present supragingivally for retention and support of core material.

Custom-made Posts

- A custom-made post can be cast from a direct pattern or an indirect one. A direct pattern utilizing autopolymerizing resin is recommended for single canals whereas an indirect procedure is more appropriate for multiple canals.

Direct Procedure

1. Trim a 14-gauge solid plastic sprue so that it slides easily into the canal to the apical end of the post preparation without binding. Cut a small notch on the facial portion to aid in orientation during subsequent steps (Fig. 17.32).
2. Mix acrylic resin monomer and polymer to a runny consistency.
3. Lubricate canal with petroleum or any other lubricating agent, on cotton wrapped on a Peeso reamer.
4. Fill the orifice of the canal as full as possible with acrylic resin applied with a plastic filling instrument. Alternatively:
   - Use the bead-brush technique to add resin to the orifice, and to the sprue.
   - In the doughy stage, roll the resin into a thin cylinder, introduce it in the canal and push it to place with the monomer-softened sprue.
5. Seat the monomer coated sprue completely into the canal. Make sure the external bevel is completely covered with resin at this time. Trying to cover it later may disturb the fit of the post (Fig. 17.33).
6. When acrylic resin becomes tough and doughy, pump the pattern in and out to insure that it will not lock into undercuts.
7. As the resin polymerizes, remove post from canal and make sure it extends till the apical end. If required, additional resin can be placed at the apical end and the post is reseated and removed. Any voids can be filled with soft dead wax e.g. utility wax. Reinsert and remove to ensure smooth withdrawal.
8. A direct pattern can also be made using inlay wax in a similar manner.
9. Add more resin or wax to form the core. Shape it in the form of the final preparation.

Indirect Procedure (Fig. 17.34)

Any elastomeric material will make an accurate impression of the root canal if wire reinforcement is placed to prevent distortion.

1. Cut pieces of orthodontic wire to length and shape them like the letter J.
2. Verify the fit in each canal. It should fit loosely and extend to the full depth of the post space.
3. Coat the wire and tray with adhesive; gingival retraction would be needed for subgingival margins. Use a die lubricant to lubricate canals and facilitate removal.

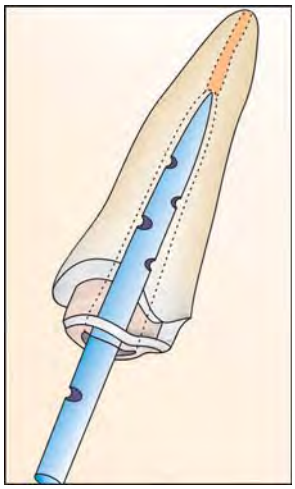


Fig. 17.32: Plastic sprue

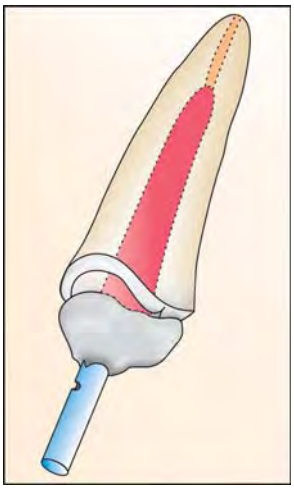


Fig. 17.33: Impression with plastic sprue and resin

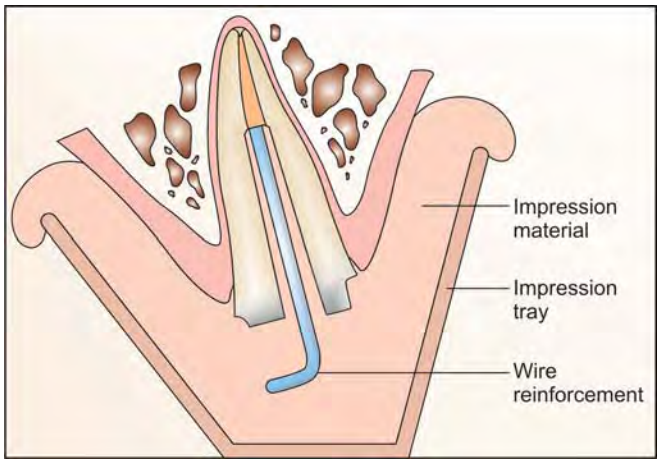


Fig. 17.34: Impression of the post space

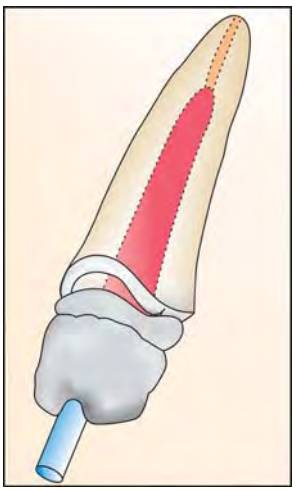


Fig. 17.35: Direct procedure for core

4. Using a lentulospiral, fill the canals with elastic impression material.
5. Seat the wire to full depth, syringe in more impression material around the prepared teeth and insert the impression tray.
6. Remove the impression, evaluate it, and pour the final cast.
7. In the cast, trim a loose fitting plastic post or sprue to fit the preparation till the apical end without binding, make a notch for orientation. Use the impression as a guide to aid in orientation.
8. Apply a thin coat of sticky wax to the plastic post and add soft inlay wax in increments. It is best to start at the most apical end and make sure that the post is correctly oriented as it is seated to adapt the wax.
9. When post pattern is made, add wax to form the core.
10. Use the impressions as a guide to evaluate whether the wax pattern is completely adapted to the post space.

CORE FABRICATION

Cast-metal Core

These are shaped in resin or wax and added to the post pattern before the assembly is cast in metal. This prevents possible failure at the post-core interface. In addition to cast posts, they can also be cast directly onto most prefabricated post systems.

Advantages

1. No failure at post-core interface.
2. Can be used with prefabricated posts.
3. Conventional high noble alloys can be used.
4. An indirect procedure can be employed, making restoration of posterior teeth easier.

Disadvantages

1. An additional appointment is required.
2. More expensive than amalgam or composite cores.
3. Casting directly onto prefabricated posts may alter their physical properties, thus weakening them.

Direct Procedure for Single-rooted Teeth (Fig. 17.35)

1. Use a prefabricated metal or custom acrylic resin post.
2. Add resin by "bead" technique, dipping a small brush into monomer and then into polymer and applying it to the post. Light cured resin may be used.
3. Slightly overbuild the core and allow it to fully polymerize.

Build-up

4. Shape the core with carbide finishing burs. Use water spray to avoid overheating of acrylic resin correct any small defects with wax (Fig. 17.36).
5. Remove the pattern, sprue and invest immediately.
6. It can be similarly built with inlay wax and shaped with carvers when the direct pattern is made with wax.

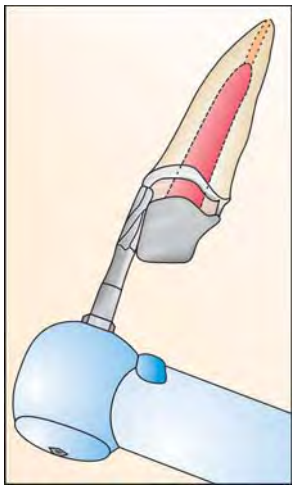


Fig. 17.36: Shaping the core

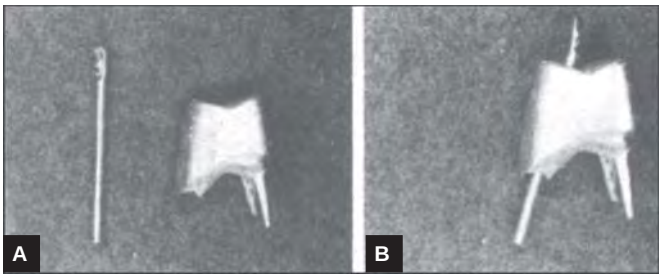
Direct Pattern for Multi-rooted Teeth

A direct pattern may be used for posterior teeth. A single piece core with auxiliary posts is used. The core is cast directly onto the post of one canal. The other canals already have prefabricated posts that pass through holes in the core. Smooth sided parallel or tapered posts are used as auxiliary posts.

1. Fit prefabricated posts into the prepared canals. One post is roughened (to which the core is cast onto); others are left smooth and lubricated. All posts should extend beyond the eventual preparation. Alternatively, the main post canal also be made by direct resin pattern and is then cast along with the core.
2. Build up the core with cold cure resin by the bead technique.
3. Shape the core to the final form with carbide burs.
4. Grip the smooth lubricated posts with force and remove them.
5. Remove, invest and cast, the core with the roughened post or resin pattern. When this is done, the holes for auxiliary posts can be refined with the appropriate twist drill.
6. After verifying the fit, cement the core and auxiliary posts to place.

Indirect Pattern for Multi-rooted Teeth

When there is limited access, indirect approach is easier to use. A multi-piece post and core is made by this method (Split casting) (Figs 17.37 and 17.38).



Figs 17.37A and B: Multipiece post and core

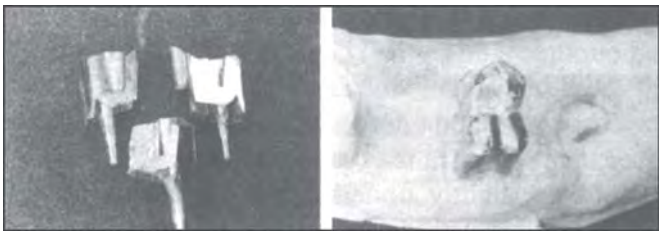


Fig. 17.38: Alternatively, interlocking sections can be made by using dovetails to interlock the sections. But this makes the procedure more complicated and is of limited benefit, especially because the final buildup is held together by the fixed cast restoration

In the final cast:

1. Wax the custom-made posts as described previously.
2. Build part of the core around the first post.
3. Remove any undercuts adjacent to other post holes and cast the first section.
4. Wax the additional sections and cast them. Each section should be waxed to ensure that no undercuts are created.
5. Cast each section separately.

Plastic Filling Materials

Amalgam, composite resin or GIC are used as core buildup materials with prefabricated posts. Due to its low strength GIC is generally not recommended unless minimal buildup is required.

Advantages

1. Maximum tooth structure can be preserved, as undercuts need not be removed.
2. Treatment requires one less appointment.
3. Fewer laboratory steps, hence cheaper.
4. Good strength.

Disadvantages

1. Long-term success may be limited by:
   - Corrosion of amalgam.
   - Low tensile strength of GIC.
   - High thermal expansion coefficients of composite resin cores.
2. Microleakage with thermocyling is found in composite and amalgam cores.
3. Certain procedures like rubber dam and matrix application may be difficult, especially with badly broken down teeth.

Amalgam Cores

They are suitable for posterior teeth, particularly when some coronal structure remains. Their merits and demerits have already been discussed.

1. A matrix band is applied to the tooth and amalgam is condensed around the posts, and built up coronally.
2. Once it sets, the band is removed and core shaped with burs as needed. A fast setting high copper amalgam is used.

Amalgam Coronal-radicular Restoration Technique (Fig. 17.39)

Used for restoring posterior teeth that are largely intact. The procedure described by Nayyar et al (1980), with amalgam used for the posts as well is conservative of tooth structure. The restoration is placed at the same appointment as the root canal obturation as the canals are still isolated, the canal anatomy is fresh in the practitioner's mind and the core can serve as a support for the provisional restoration.

1. Remove the gutta-percha from the pulp chamber as well as 2-4 mm into each root canal if less than 4 mm of coronal height remains. Use a heated plugger.
2. Remove any existing restoration, undermined enamel, or carious or weakened dentin. Establish the cavity form. Even if cusps are missing, pins are not normally required because of extension into root canals.
3. If it is suspected that the floor of the pulp chamber is thin, then protect it from condensing pressures with a cement base.
4. Fit a matrix band for badly broken down teeth or an orthodontic band may be used.
5. Condense the first increments of amalgam into the root canals with a plugger.
6. Fill the pulp chamber and coronal cavity in the conventional manner.
7. Carve the alloy to shape. The impression can be made immediately. Alternatively, the amalgam can be built to anatomic contours and then shaped with burs.

Composite Resin Cores

These are built up using crown forms (Fig. 17.40). A clear crown form permits use of a light activated composite, while a polycarbonate form can be used with chemically activated composite.

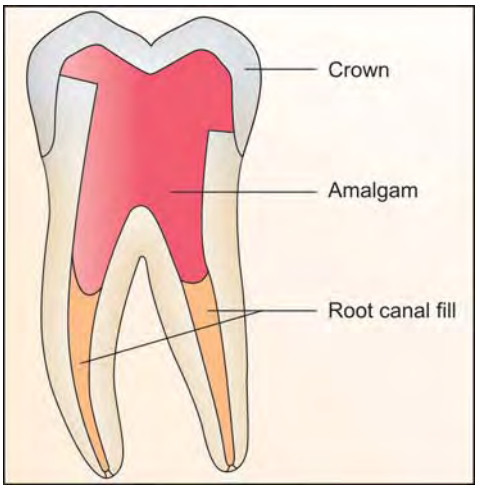


Fig. 17.39: Nayyar core

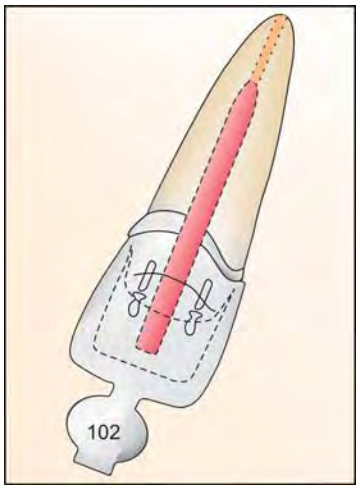


Fig. 17.40: Crown forms

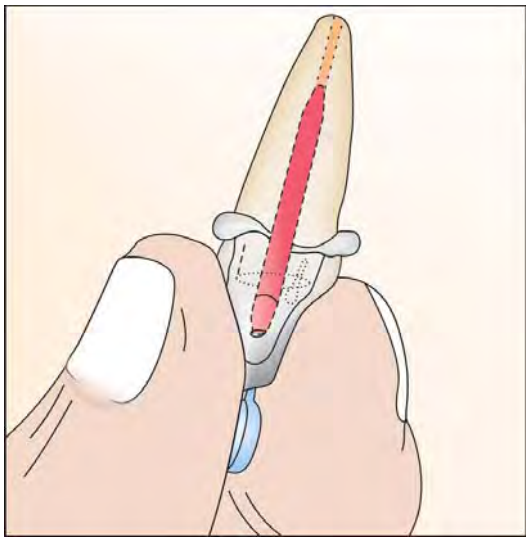


Fig. 17.41: Polymerization of resin in crown forms

1. If a polycarbonate crown form is used, place a separating medium.
2. Fill the crown form with resin and hold it in position over the protruding dowel until it polymerizes (Fig. 17.41).
3. Remove the matrix and shape the core with burs to the form of a crown preparation.
4. The gingival finish line should be in tooth structure.

Alternatively, the core can be built with light activated composite in increments without using a crown form.

Investing and Casting

The post-core pattern is sprued on the incisal or occlusal end (Fig. 17.42). About 1.0 to 2.0 cc of extra water is added to the investment and a liner is omitted to increase the casting shrinkage (Shillingburg). This results in a slightly smaller post that does not bind in the canal, and it also provides space for the cement. A tight fit may cause root fracture. When resin is used, the pattern should remain for 30 minutes longer in the burnout oven to ensure complete elimination of the resin.

After endodontic treatment, if a cast post and core is planned, a provisional crown with attached temporary post can be fabricated for the teeth with limited supragingival structure (Fig. 17.43). A provisional restoration is also needed while the post and core is being fabricated to prevent drift of adjacent and opposing teeth. Fitting a wire paper clip (e.g. or orthodontic wire) into the prepared canal or using a temporary post available with proprietary post systems can do this. Restoration is then conveniently fabricated with autopolymerizing resin with the direct technique.

Fig. 17.42: Spruing of post and core pattern

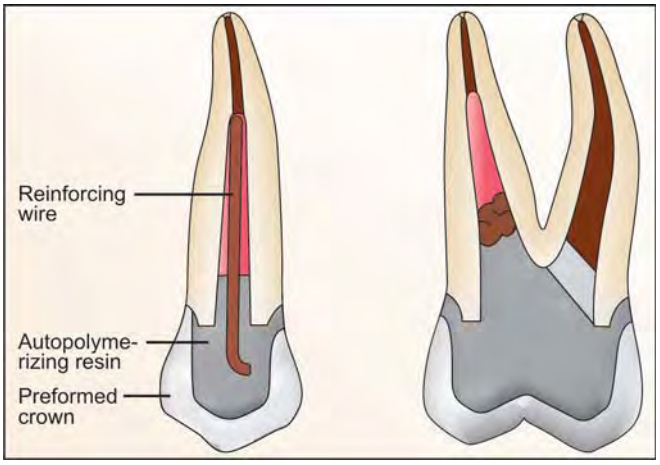


Fig. 17.43: Provisional crowns and posts

The final post, core and crown should be fabricated as soon as possible, because microleakage can contaminate the post space and endodontic fill. Provisional restorations should be used with extreme caution because partial loss of the cement seal may go undetected for some time. This leakage can lead severe carious invasion and loss of tooth. In addition to caries, leakage can jeopardize the success of endodontics.

Try-In and Cementation

Any cement may be used if retention and resistance of the post are adequate. The choice of cement may become more important if the post has a poor fit in the canal. When resin cements are used, the post should be cemented with auto-cure or dual-cure resin cement because of limited light penetration into the root. Irrigation with 2.5 cc of 17 percent EDTA to chelate calcium followed by 2.5 cc of 5.25 percent NaOCl to flush away debris, has been recommended to remove smear layer and improve retention. Also, microbrushes can be used to deliver etchants and bonding agents deep into the canal.

Prefabricated Posts

1. Once the post has been selected, make a thin mix of cement and coat the post with it.
2. Introduce cement into the post space with a plastic instrument. Use a lentulospiral to ensure that the walls are coated with cement. According to Shillingburg, retention can be increased by as much as 90 percent if a lentulospiral is used (Fig. 17.44).
3. Push the post slowly to place allowing excess cement to escape. Parallel-sided posts should have an escape vent to allow escape of excess cement.
4. Hold the post with finger pressure until initial set occurs. Then remove excess cement from around post head and pins.
5. Fabricate core, prepare it similar to a tooth preparation. Take impression for final restoration.

Custom-made Posts

1. Check the fit of the post-core in the tooth by seating it with light pressure.
2. If it binds in canal or will not seat completely, air abrade the post and reinsert it in the canal. Relieve any shiny spots.
3. The core portion of the casting should be polished. If required, a vertical groove, from apical end to contrabevel, can be cut in the post to provide an escape vent for the cement (Fig. 17.45).
4. The canal should be cleaned with a cavity cleaner to remove lubricant / temporary cement which may inhibit set of resin cements and decrease retention.
5. Cement the post as for prefabricated posts.
6. Modify the core if necessary. Make an impression for the final restoration.

Cementation of Preformed Posts or Cast Post and Cores with Resin Cement

A technique using Panavia-21 has been described.

Treatment of Canal

1. Remove filling material and prepare the length and diameter of the canal as appropriate for the size of post to be placed, or prepare a cast post and core.
2. Dispense one drop of each ED PRIMER Liquid A and Liquid B into a well of the mixing dish and mix for three-five seconds with a small sponge pledget. Place the mixture on any coronal dentin and into the canal. After 60 seconds evaporate the

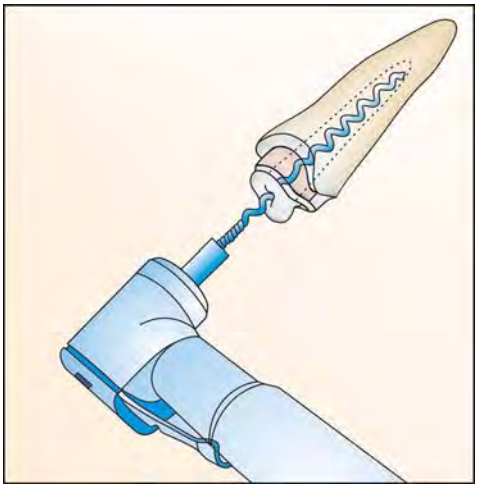


Fig. 17.44: Using a lentulospiral for cementing

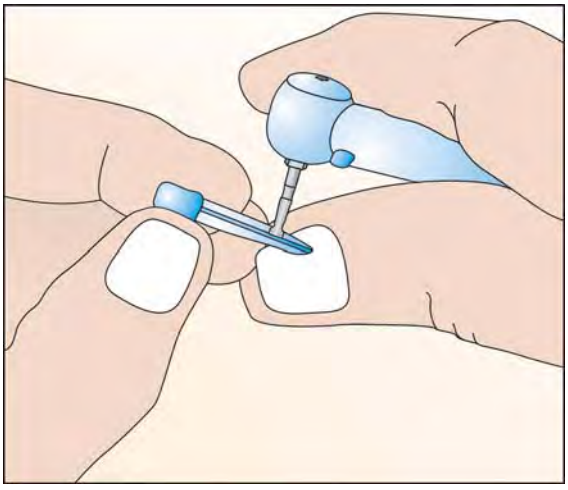


Fig. 17.45: Venting of post

volatiles with a gentle stream of air; the surface will appear glossy.
Note: Do not apply ED PRIMER to the metal. Do not rinse.

Treatment of Preformed Post or Cast Post and Core

1. Preformed stainless or titanium posts should be sandblasted with 30-50 micron alumina particles at an air pressure of 4.2-7 kg/cm^2 (60-100 PSI); two to three seconds per cm^2 will produce a matte finish. Fiber posts can also be sandblasted to increase retention.
2. Cast post and core of precious or semi-precious metal should be sandblasted as above and then tin-plated. A layer of tin approximately 0.5 micron thick should be deposited. To avoid contamination, do not touch the tin-plated surface.
3. After sandblasting and after tin-plating, wash the post in a stream of water for one minute then ultrasonically clean for two-three minutes in a neutral detergent solution.
   Note: The prepared canal and post must be kept dry and contamination free.

Usage of PANAVIA 21 Paste

1. Remove the syringe cap and slowly rotate the dispensing knob one full turn clockwise until it clicks. This dispenses the proper ratio and amount of PANAVIA 21 Catalyst and Universal paste for the cementation of one preformed post or cast post and core. If more PANAVIA 21 paste is required, dispense an additional full turn.
   Note: PANAVIA 21 paste must always be dispensed in increments of full turns.
2. Mix the dispensed Catalyst and Universal pastes for 20-30 seconds, creating a smooth, uniform paste. Because of PANAVIA 21's anaerobic properties the mix should be spread in a thin layer on the pad until ready to use, else it will start setting.

Seating the Preformed Post or Cast Post and Core

1. Apply a thick, even layer of PANAVIA 21 paste to the prepared, cleaned and dried post, being careful to avoid air entrapment.
   Note: Do not additionally apply PANAVIA 21 paste to the canal primed with ED PRIMER as this will accelerate the set of PANAVIA 21 paste.
2. Seat the post and apply pressure for about 60 seconds.
3. For a cast post and core, remove the excess PANAVIA 21 and with a disposable brush tip apply OXYGUARD II to the margin. After three minutes remove the OXYGUARD II with cotton roll and water spray.
4. For a preformed post and amalgam or composite used as a build-up material, PANAVIA 21 expressed from the canal during post seating can be used as cement for the build-up material.
5. Continue with normal abutment and crown procedures.

Wiptam Technique (Figs 17.46 and 17.47)

The author has used chrome-cobalt wire as a post with a gold core cast on to for about thirty years without problems. The technique is simple and economical. The canal is prepared, using a twist drill (1.0-1.5 mm depending of the diameter of the root) and the

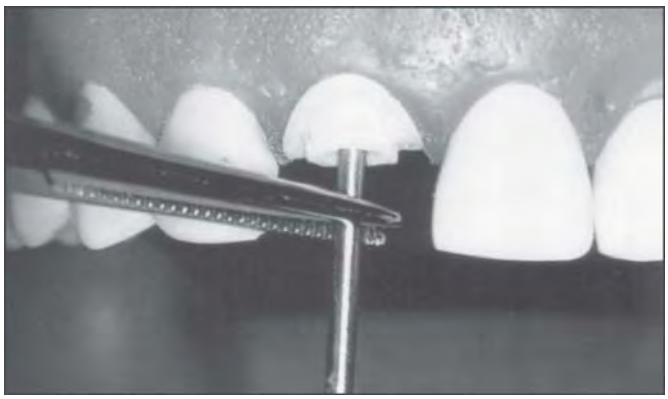


Fig. 17.46: Fitting of Co-Cr Wire

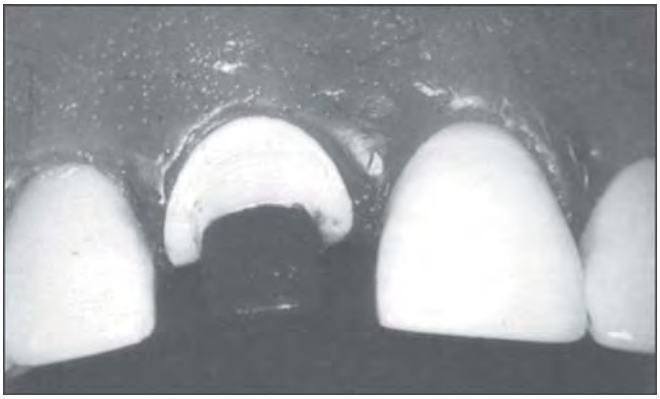


Fig. 17.47: Finished pattern

matching size of wire (Wiptam) is fitted so that it projects to lie well within the proposed core build-up. An antitorsion lock is produced by cutting minimum lateral extensions in the coronal part of the canal. The tooth is lubricated and the projecting end of the post is notched to provide retention for the gold. A thin mix of Duralay (a pattern acrylic), is coated over the wire and into the orifice of the canal. As it starts to polymerize, it is shaped with a plastic instrument dipped in monomer and is slightly over-built. It is then left to harden (60-90 seconds).

When it hardens, it is pulled out of the canal, shaped and re-inserted checking the occlusion in all excursions to ensure sufficient room for the proposed restoration. Blue wax is then melted around the part of the wire and plastic which fits the coronal orifice and, while the wax is molten the post/core is re-inserted and pressed. Wax is thus forced into the prepared root canal and anti-torsion lock to obtain good retention. After removal of the excess wax at the margins, the post core is removed, sprued and invested, and the core cast in hard gold.

FINAL RESTORATION

The final component of the endodontic reconstruction is the coronal restoration. All coronal restorations:

1. Re-establish function and esthetics.
2. Isolate the dentin and endodontic fill material from microleakage.
3. Protect remaining tooth structure.
4. Maintain the health of the periodontium.

Choice of restoration depends on the type of tooth and esthetic demands:

1. *Posterior teeth:* All metal or metal-ceramic crowns. If post and core has not been given then a full occlusal coverage onlay may be given.
2. *Anterior teeth:* Metal-ceramic or all ceramic crown.

The amount of tooth structure remaining after final preparation has the greatest importance in determining the design of the post and core. Tooth structure that appears adequate before tooth preparation may be grossly unatisfactory after occlusal and axial reductions. Therefore, the initial crown preparation is first completed and the bulk and position of the prepared tooth structure is evaluated for post and core selection.

The coronal preparation of an endodontically treated tooth involves the same principles as the preparation of a vital tooth whose structure has been altered by caries and previous restorations. The core should be shaped like the final tooth preparation to provide an ideal foundation upon which the casting can be fabricated and which provides adequate retention and resistance to rotation for the final restoration.

Once restored with a crown, the underlying sound tooth structure provides greater resistance to fracture than any type or design of post. Natural tooth structure should be preserved during all phases of post space preparation and crown preparation.

SUGGESTED READING

1. Cohen and Burns. Pathways to the Pulp. 8th ed; Mosby, St. Louis, 2002.
2. Freedman GA. Esthetic post and core treatment. Dent Clin N Am, 2001;45:103-16.
3. Gutmann JL. The dentin-root complex: Anatomic and biologic considerations in restoring endodontically treated teeth. J Prosthet Dent 1992;67:458-67.
4. Ingle and Bakland. Endoodontics. 4th ed; Williams and Wilkins, Malvern, 1994.
5. Koutayas SO, Kern M. All ceramic posts and cores: The state of the art. Quintessence Int 1999;30:383-92.
6. Rosenstiel, Land and Fujimoto. Contemporary Fixed Prosthodontics. 2nd ed. Mosby, St. Louis, 1995.
7. Stock, et al. Endodontics. 2nd ed. Mosby-Wolfe, London, 1995.
8. Weine. Endoodntic therapy. 6th ed. Mosby, St. Louis, 2004.

18 Endodontic Microsurgery

MAGNIFICATION AND ILLUMINATION IN ENDODONTICS

Introduction

Most conventionally root canal treated teeth have good success rate. But failure seems inevitable in about 5-10 percent of cases which may necessitate the need for surgical endodontics. In recent years, with the advent of loupes and microscopes, there has been a tremendous change in the concepts and procedures followed in endodontics surgery such as change in instrument size, use of ultrasonic tips, apicoectomy procedure, suture materials, techniques and procedures, etc.

Loupes (Fig. 18.1)

Historically, dental loupes have been the most common form of magnification used in apical surgery. Loupes are essentially two monocular microscopes with lenses mounted side by side and angled inward (convergent optics) to focus on an object. The disadvantage of this arrangement is that the eyes must converge to view an image. This convergence over time will create eyestrain and fatigue and, hence, loupes were strenuous for lengthy procedures. Most dental loupes used today are compound in design and contain multiple lenses with intervening air spaces. This is a significant improvement over simple magnification eyeglasses but falls short of the more expensive prism loupe design.

Fig. 18.1: Loupes

Prism loupes are the most optically advanced type of loupe magnification available today. They are actually low-power telescopes that use refractive prisms. Prism loupes produce better magnification, larger fields of view, wider depths of field, and longer working distances than other types of loupes. Only the Surgical operating microscope provides better magnification and optical characteristics than prism loupes. The disadvantage of loupes is that 3.5-4.5X is the maximum practical magnification limit. Loupes with higher magnification are available but they are quite heavy and if worn for a long period of time can produce significant head, neck, and back strain. In addition, as magnification is increased, both the field of view and depth of field decrease, which limits visual accuracy.

Visual accuracy is heavily influenced by illumination. An improvement in using dental loupes is obtained when a fiberoptic headlamp system is added to the visual armamentarium. Surgical headlamps can increase light levels as much as four times that of traditional dental operatory lights. Another advantage of the surgical head lamp is that since the fiberoptic light is mounted in the center of the forehead, the light path is always in the center of the visual field.

DENTAL OPERATING MICROSCOPE (FIGS 18.2 AND 18.3)

The success of endodontics relies on the localization of the entire root canal system and its subsequent cleaning, shaping, and three-dimensional obturation. Several magnification systems have been advocated over the years.

Fig. 18.2: Zeiss OPMI PROergo (Carl Zeiss Surgical Inc)

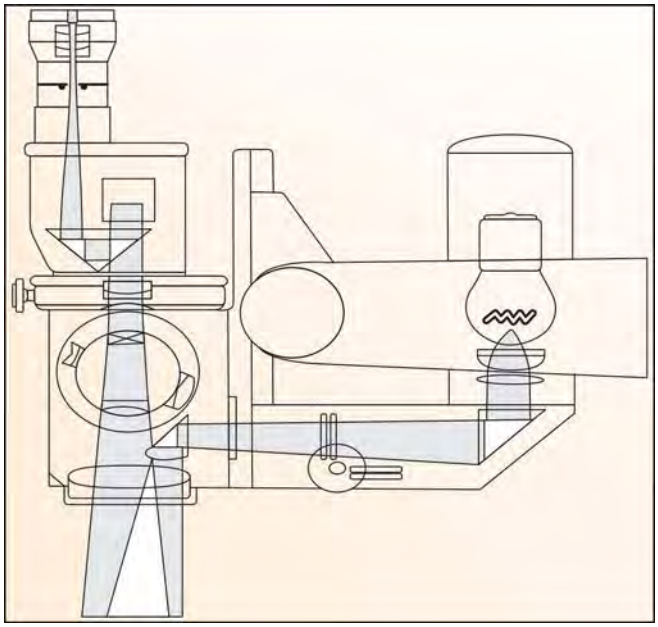


Fig. 18.3: Cross-sectional diagram of a typical 5-step SOM Thornwood, NY, USA) with magnetic clutches, power zoom, and power focus on the handgrips

Introduction of the surgical operating microscope (SOM) to endodontics has dramatically changed the practice of the specialty.

Dental operating microscope is one of the key advancement that endodontics has seen in the early 1990s.The incorporation of microscope in clinical endodontics has had profound effects on the way endodontics is done and has changed the field fundamentally. The microscope provides great magnification and illumination and functions as an extension of loupes. It provides a magnification of 4X to 25X as compared to 2X to 4X provided by loupes. The optimum magnification required for endodontic practice ranges from 8X to 24X which is needed to locate hidden canals, detect microfractures, distinguish between chamber floor and dentin, and identify isthmuses and small anatomic entities', recognition and treatment are important for the success of endodontic therapy.

In conventional endodontics, the microscope is most useful for locating canals after the access is made. It is extremely useful for post removal using ultrasonic instruments and for perforation repair. These were the procedures that previously were done largely by "feel". The advent of microscope in modern endodontic therapy facilitates a primarily visually-guided, secondarily sensory-aided endodontic procedure.

Comparison of Traditional and Microsurgery

Type of procedure	*Traditional surgery*	*Microsurgery*
Osteotomy	Bigger (10 mm)	Small (<5 mm)
Root apex identification	Difficult	Easy
Root end preparation	Difficult	Easy
Bevel angle	Difficult (45°)	Easy (0-10°)
Root surface inspection	Difficult	Always possible
Root end filling	Not precise	Precise

PREREQUISITES FOR THE USE OF MICROSCOPE IN NON-SURGICAL ENDODONTICS

1. *Rubber dam placement:* The placement of rubber dam prior to any endodontic procedure is an absolute requirement for isolation. Here, the rubber dam placement is necessary because direct viewing through the canal with the microscope is difficult, if not impossible. A mirror is needed to reflect the canal view that is illuminated by focused light and

magnified by the lens of the microscope. If the mirror is used for this purpose without a rubber dam, then the mirror would fog immediately from the exhalation of the patient thus rendering illumination and magnification totally useless. To absorb reflected bright light and to accentuate the tooth structure, it is recommended to use blue or green rubber dams.

2. *Indirect view and patient's head position:* It is nearly impossible to view the pulp chamber directly under the microscope. Instead, the view seen through the microscope lens is a view reflected by the mirror. To maximize the access and quality of the view by indirect means, the position of he patient is important. The optimal angle between microscope and mirror should be 45° and the clinician should be able to obtain this angle without requiring the patient to assume an uncomfortable position. The maxillary arch is rather easy for indirect viewing. Basically, the patients head is adjusted to create a 90° angle between the maxillary arch and binocular. In this position, the mirror placement will be close to 45° for best viewing.
3. *Mouth mirror placement:* Mirror should be placed away from the tooth within the confines of the rubber dam. If the mirror is placed close to the tooth, then it will be difficult to use other endodontic instruments. Readjusting mirror may necessitate the refocusing of the microscope. However, the operator will gain the correct placement automatically with practice.

ADVANTAGES OF MICROSCOPES

1. Visualization of the surgical field.
2. Evaluation of surgical technique.
3. Fewer radiographs required.
4. Report to the referring dentists and insurance companies.
5. Documentation for legal purposes.
6. Patient education through video.
7. Video libraries used for teaching programs.
8. Marketing the dental practice.
9. Less occupational stress.

How Does it Work?

- Magnification
- Illumination
- Documentation
- Accessories

Magnification

It is determined by:

- Power of the eyepiece
- Focal length of the binoculars
- Magnification change factor
- Focal length of objective lens.

Eyepieces are available in different magnifications like 6.3X, 10X, 12.5X, 16X and 20X. The side of viewing in eyepiece will have a rubber cup. This is turned down if the operator uses eye glasses. The diopter settings (distance between two binocular tubes) are -5 to +5 and are used for accommodation, which is the ability to focus the lens of the eyes.

The inclination of the binoculars will be usually 45° to the head of the microscope. This inclination may help better visualization of the maxillary arch. But Straight tube is preferred over the inclined tube for endodontic procedures.

Magnification changers or power zoom changers may be manual or automatic and are usually located in the head of the microscope.

Manual zoom changer consists of a turret connected to a dial located on the side of microscope housing. The dial positions one lens in front of the other within changer. It produces a fixed magnification factor or value available as three step changer and five step changer.

Power zoom changer consists of a series of lenses that move back and forth on a Focusing ring.

Before the microscope is used for any procedure, it must be made pan focal, i.e. it is in focus thought the entire range of magnification.

Focal length of objective lens determines the operating distance between the operating microscope and the surgical field. If it is removed, the microscope focuses at infinity and functions as a pair of binoculars. A variety of objective lenses are available with focal length ranging from 100 to 400 mm. A 175-mm lens focuses about 7 inches and a 200-mm about 8 inches. A 200-mm objective lens is recommended because there will be adequate room to place surgical instruments and still be close to the operating field.

Charts are available that explain magnification as related to eyepiece power, binocular focal lengths, magnification factor and the objective lenses and also the depth of view. This information can be summarized as follows:

1. If the focal length of objective lens is increased, magnification and illumination decreases and field of view increases.

2. If the focal length of binoculars is increased magnification is increased and field of view is reduced.
3. If the magnification factor is increased, magnification is increased and field of view is reduced.
4. If the power of the eyepiece is increased, magnification is increased and field of view is reduced.
5. If the magnification is increased, depth of field is reduced.

Illumination

Commonly used source of light is a 100 W xenon halogen bulb. A rheostat cooled by a fan controls the intensity of the light. The light is reflected through a condensing lens to a series of prisms and then to the objective lens on the way to the surgical field. It is reflected back through the objective lens, magnification changer, lens, binoculars and exits to the eye as two separate beams of light. The separation produces stereoscopic effect that allows the clinicians to see the depth of the field.

A beam splitter can be inserted on the pathway of light, which supplies light to accessories such as a camera or an auxiliary observation tube.

As magnification increases, the effective aperture of the microscope is decreased, and more light is needed as the optics absorb more light in higher magnification.

Illumination with operating microscope is coaxial with the line of sight, i.e. light is focused between eyepieces in such a fashion that the clinician can look into the operating site without any shadows. This is possible as the microscope uses Galilean optics. Galilean optics focuses at infinity and sends parallel beams of light to each eye. With parallel light, the operator's eyes are at rest as though he or she were looking off into the distance. Because of this, lengthy operation can be performed without fatigue.

Documentation

This is the ability to produce quality slides and videos.

The beam splitter produces illumination for photographic and video documentation, and can be connected to photo and cine adapters to which 35 mm video camera can be attached. An additional strobe may be necessary over the objective lens in these cases.

Video cameras are connected to video printers and to a cassette recorder. The microcomputer in the video printer automatically analyses the image. Prints are created in 70 seconds using a high-density sublimation dye.

Accessories

1. Pistol grips/bicycle style handles.
2. Observation ports/beam splitter/teaching purpose.
3. Assistant observation devices.
   a. High resolution monitors
   b. LCD screens
   c. Assistants binoculars.

USES OF DENTAL OPERATING MICROSCOPE (RADIOGRAPHIC ILLUSTRATIONS)

Retreatment of Complex Cases (Figs 18.4A and B)

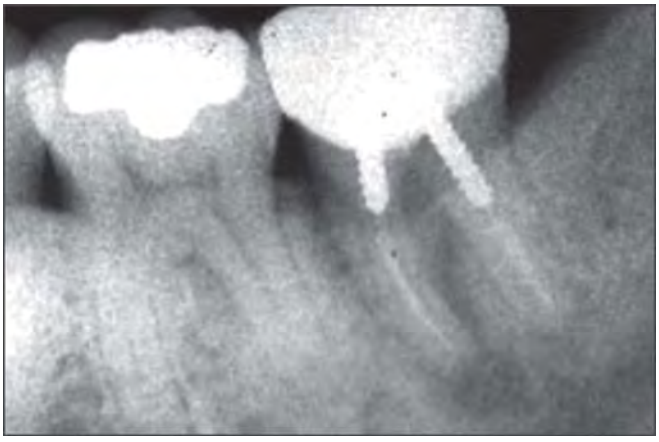


Fig. 18.4A: Lower molar with posts and crown and incomplete root canal treatment

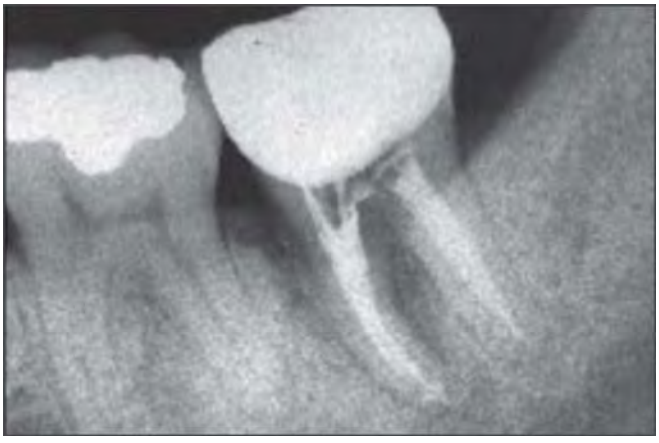


Fig. 18.4B: Final radiograph after retreatment. A third untreated canal was located with the SOM

Removal/Retreatment (Figs 18.5 and 18.6)

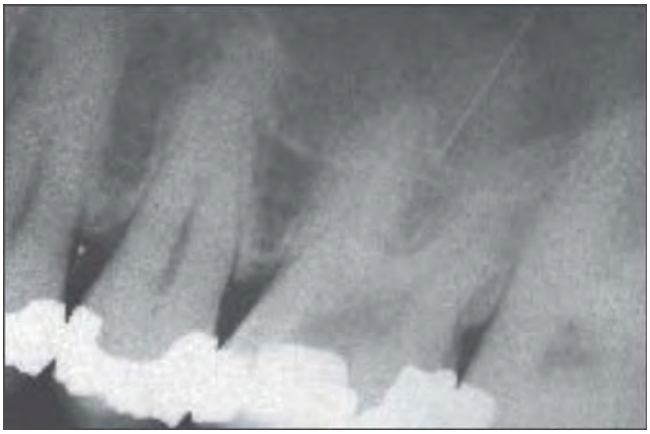


Fig. 18.5A: Upper molar with a separated Ni Ti file in the palatal canal

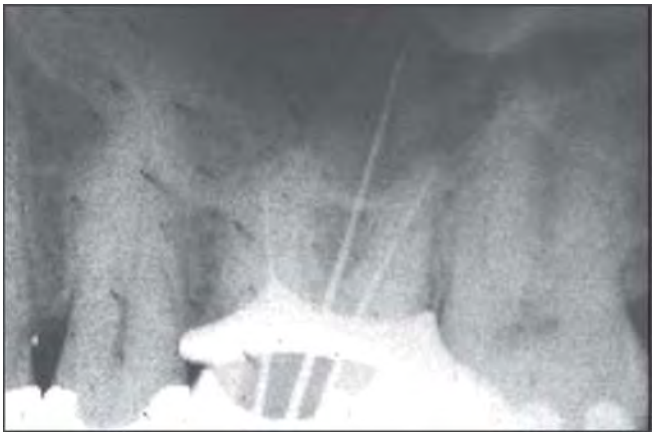
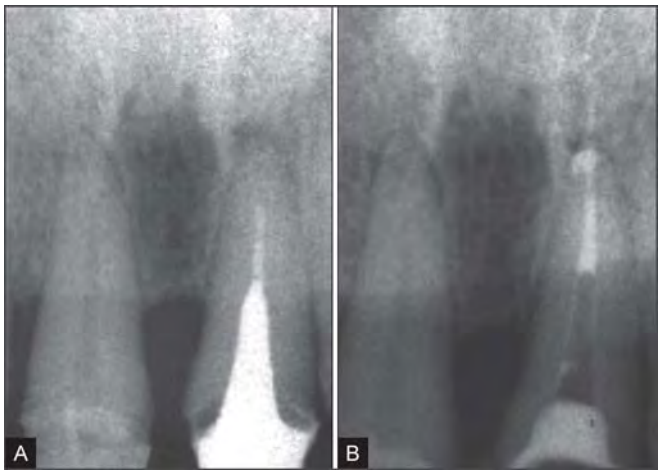


Fig. 18.5B: Working radiograph showing successful removal of separated instrument



Figs 18.6A and B: Removal of foreign material: (A) Cast post and cement filling material; (B) Retreatment completed

More Uses of SOM – Diagnosis (Fig. 18.7)

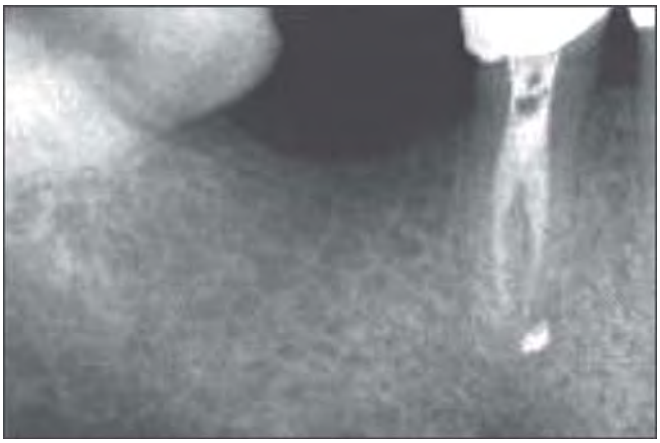


Fig. 18.7: A lower premolar with two separate canals

Upper second molars with four canals have become the norm rather than the exception.

INDICATIONS FOR ENDODONTIC SURGERY

1. Need for surgical drainage
2. Failed nonsurgical endodontic treatment
   - Irretrievable root canal filling material
   - Irretrievable intraradicular post
3. Calcific metamorphosis of the pulp space
4. Procedural errors
   - Instrument fragmentation
   - Non-negotiable ledging
   - Root perforation
   - Symptomatic overfilling
5. Anatomic variations
   - Root dilaceration
   - Apical root fenestration
6. Biopsy
7. Corrective surgery
   - Root resorptive defects
   - Root caries
   - Root resection
   - Hemisection
   - Bicuspidization
8. Replacement surgery
   - Intentional replantation (extraction/replantation.
   - Post-traumatic
9. Implant surgery
   - Endodontic
   - Osseointegrated

CONTRAINDICATIONS TO SURGICAL ENDODONTICS

There are few contraindications to endodontic surgery:

1. Patient factors including the presence of severe systemic disease and psychological considerations.
2. Anatomical factors including:
   - Unusual bony or root configurations
   - Lack of surgical access
   - Possible involvement of the Neurovascular bundle
   - Where the tooth is subsequently unrestorable
   - Where there is poor supporting tissue
3. The skill, training and experience of the operator also have an influence.

APICOECTOMY—INDICATIONS

Common indications for resection of the apical portion of the root during periradicular surgery.

- Removal of pathologic processes like symptomatic fractured root apices, suspected contaminated apices (retained microorganisms and biofilm), root apices with tenaciously attached pathologic tissue, and removal of foreign material in the apical portion of the canal.
- Removal of anatomic variations such as apical deltas, accessory canals, apical canal bifurcations, severe curves, lateral canals, and calcifications.
- Removal of operator errors in non-surgical treatment includes complications such as ledges, blockages, zips, perforations, and separated instruments.
- Enhanced removal of the soft tissue lesion so as to gain access to deeply placed soft tissue around the root in order to secure an adequate biopsy.
- Access to the canal system when they are blocked with, for example, a post core restoration, and the apical portion of the canal has not been properly cleaned, shaped, or obturated, root-end resection (RER) may be necessary to manage the untreated portion of the root canal system.
- Creation of the apical seal in cases of failed non-surgical cases, Root end resection may be necessary to create an environment for access and vision so that an adequate apical seal can be achieved.
- Reduction of fenestrated root apices—Possible contributing factors include age, anatomical anomalies, orthodontics, and trauma.
- Evaluation for aberrant canals and root fractures—Root end resection will potentially expose these aberrant canal communications, complete or incomplete vertical fractures, etc. These can be detected on a stained root-end bevel.

APPLICATION OF SOM IN APICAL MICROSURGERY

Microsurgical Armamentarium (Fig. 18.8)

Important advantage of using the operating microscope is in evaluating the surgical technique. Those pioneers who began using the microscope some two decades ago observed early on that most traditional surgical instruments were too large to be placed accurately in small places, or that they were too traumatic when used to manage soft and hard tissue. This led to the development of a microsurgical armamentarium and the true practice of apical microsurgery.

Apical microsurgery can be divided into 20 stages or sections.

These are flap design, flap reflection, flap retraction, osteotomy, periapical curettage, biopsy, hemostasis, apical resection, resected apex evaluation, apical preparation, apical preparation evaluation, drying the apical preparation, selecting retrofilling materials, mixing retrofilling materials, placing retrofilling materials, compacting retrofilling materials, carving retrofilling materials, finishing

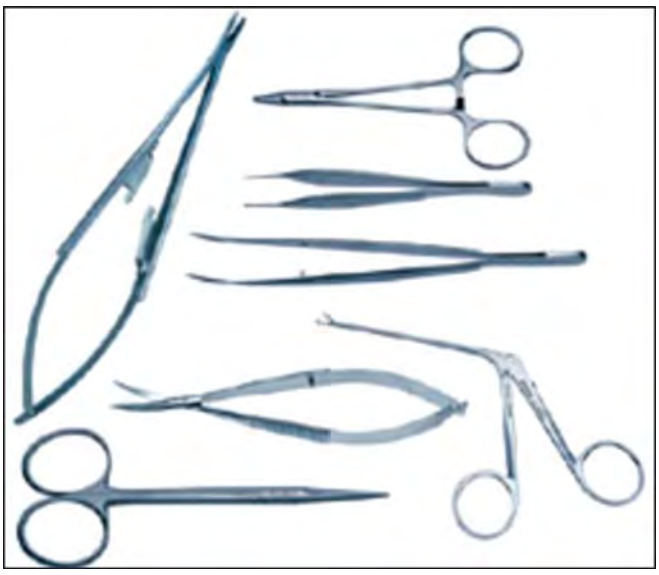


Fig. 18.8: Microsurgical armamentarium

Fig. 18.9: A variety of micro-scalpels sized 1-5 used for precise incision

Fig. 18.10: Periosteal elevators for flap reflection

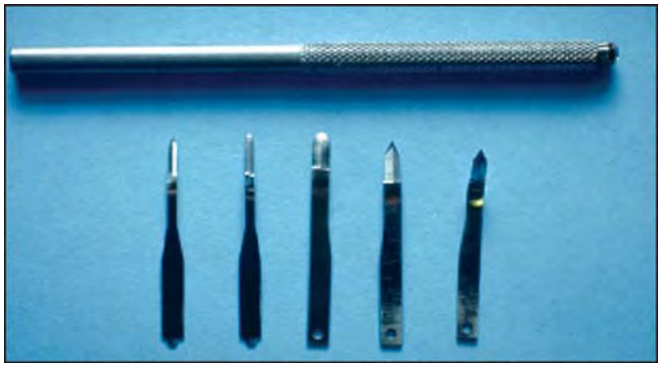


Fig. 18.11: Rubinstein Mini-Molts

retrofilling materials, documenting the completed retrofill, and tissue flap closure.

Numerous instruments have been designed that can be used in the various stages. It is appropriate to discuss those that are of particular importance to the microscopic component of apical surgery, many of which have been recently introduced.

After anesthesia is obtained, micro-scalpels (SybronEndo, Orange,CA,USA) (Fig. 18.9) are used in the design of the tissue flap to incise delicately the interdental papillae when full-thickness flaps are required.

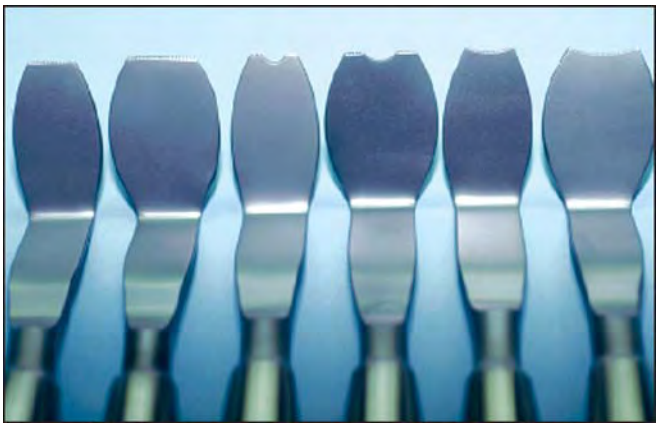


Fig. 18.12: Minnesota retractor

Vertical incisions are made 1.5 to 2 times longer than in traditional apical surgery to assure that the tissue can be easily reflected out of the light path of the microscope.

Historically, tissues have been reflected with a Molt 2-4 curette or a variation of the Molt 2-4. This instrument is double ended and the cross-sectional diameters of the working ends are 3.5 and 7.0 mm. Under low-range magnification, it can readily be seen that even the smallest end of this instrument is too large to place beneath the interdental papilla without causing significant tearing and trauma to the delicate tissues (Fig. 18.10).

Rubinstein Mini-Molts (JEDMED Instrument Company) (Fig. 18.11) are now available in two configurations whose working ends are 2.0 and 3.5 mm and 2 and 7 mm. The smaller ends of these instruments provide for atraumatic elevation of the interdental papilla making flap reflection more predictable and gentle to the tissues.

Once the tissue has been reflected, instruments such as the Minnesota retractor (Fig. 18.12) or Kim-Pecora retractor can be used to retract the tissue away from the surgical field while assuring visual access. A series of six retractors offering a variety of serrated contact surfaces that are flat, notched, and recessed have been introduced to allow the operator several options for secure placement in areas of anatomical concern. Among these are placements over the nasal spine, canine eminence, and mental nerve.

The blades of the retractors are designed to retract both the flap and the lip and are bent at 1100 to keep

the retractor and operators hand out of the light path of the microscope.

The handles are ergonomically designed to decrease cramping and fatigue and can be held in a variety of grips. A seventh retractor offering universal positioning has recently been introduced.

Because the SOM enhances vision, bone removal can be more conservative. Handpieces such as the Impact Air 45 (SybronEndo) are used, When using the handpiece, the water spray is aimed directly into the surgical field but the air stream is ejected out through the back of the handpiece, thus eliminating much of the splatter that occurs with conventional high-speed handpieces. These are extremely efficient and are recommended for hard-tissue removal.

Burs are 9 mm in length and have only four flutes, which result in less clogging. With the use of an SOM, high-speed surgical burs can be placed even in areas of anatomical jeopardy with a high degree of confidence and accuracy.

Under the SOM, periapical curettage is facilitated because bony margins can be scrutinized for completeness of tissue removal. A Columbia 13-14 curette is recommended in small crypts because it is curved and can reach the lingual aspect of a root. After the Columbia 13-14 is used, the Jacquette 34-35 scaler is recommended to remove the remainder of the granulomatous tissue.

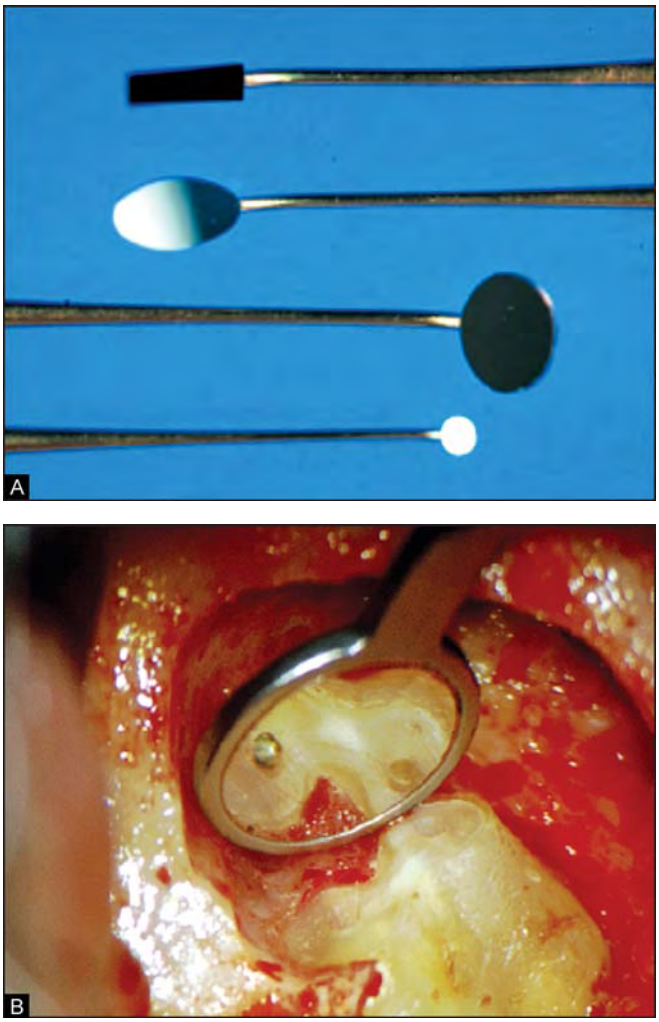
After the root-end resection has been completed, the bevelled surface of the root can be examined under mid-range magnification. Using a small CX-1 micro explorer (SybronEndo), small micro fractures and isthmuses can readily be seen

Since the introduction of ultrasonic technology in the early 1990s by Carr, apical preparations have been made with ultrasonic tips. These tips are driven by a variety of commercially available ultrasonic units, which are self-tuning regardless of changes in tip or load, for maximum stability during operation. A piezoelectric crystal made of quartz or ceramic located in the handpiece is vibrated at 28, 000-40, 000 cycles per second and the energy is transferred to the ultrasonic tip in a single plane. Dentin is then abraded microscopically. Continuous irrigation along the tip cools the cutting surface while maximizing debridement and cleaning.

Most ultrasonic tips are 0.25 mm in diameter and approximately 3.0 mm in length. When used, they are placed in the long axis of the root so that the walls of the preparation will be parallel and encompass about 3 mm of the apical morphology. As the piezoelectric crystal in the handpiece is activated, the energy is transferred to the ultrasonic tip, which then moves forward and backward and dentin is "brush cut" away in gentle strokes. The combination of the SOM and ultrasonic tips makes previously challenging cases routine. By combining magnification and ultrasonic technology, apical conservation of root dentin is possible. This procedure should be observed while using mid-range magnification of the SOM.

MICROMIRRORS (FIGS 18.13A AND B)

Another development in apical microsurgery has been the introduction of the surgical micromirror. Among



Figs 18.13A and B: Micromirrors

the early pioneers of micromirrors was Dr Carlo Zinni, an otorhinolaryngologist from Parma, Italy. Being an early user of the microscope, Zinni recognized the need to view the pharynx and larynx indirectly for proper diagnosis. Zinni crafted the first polished stainless steel mirrors from which the early endodontic micromirrors were developed.

Micromirrors come in a variety of shapes and sizes, and have diameters ranging from 1 to 5 mm. There have been many surfaces used on micromirrors: polished stainless-steel, polished tungsten carbide, and diamond-like coating.

Recently introduced micromirrors have a rhodium coating. Rhodium is extremely hard and durable and is unsurpassed in reflectivity, clarity, and brightness. They are front surface, scratch resistant, and autoclavable. Using the SOM, it is now possible to look up into the apical preparation to check for completeness of tissue removal. Before using micromirrors, it was impossible to assess the thoroughness of apical preparation leading to incomplete removal of old root canal-filling material and debris from the facial wall of the apical preparation.

A variety of small pluggers ranging in diameters from 0.25 to 0.75 mm are available to condense the cushion of gutta-percha (Fig. 18.14). Facial wall debris can further be addressed by removal with a back action ultrasonic tip. Virtually all modern-day ultrasonic tips have some degree of back action in their design. This angle can vary between 70.0 and 80.0

Once the apical preparation has been examined, it should be rinsed and dried. Traditionally, apical preparations were dried with paper points before placing retrofilling materials. This allowed for thorough adaptation of retrofilling materials against the walls of the cavity preparation and decreased the chances of creating material voids. Microcontrol of air and water is now accomplished by using a small blunt irrigating needle mounted on a Stropko Irrigator (SybronEndo) (Figs 18.15A and B).

The irrigator fits over a triflow syringe and allows for the directional microcontrol of air and water. Air pressure can be regulated down to 4 psi. Now the bevelled root surface and the apical preparation can be completely rinsed and dried before inspection with micro-surgical mirrors. Anatomical complexities,

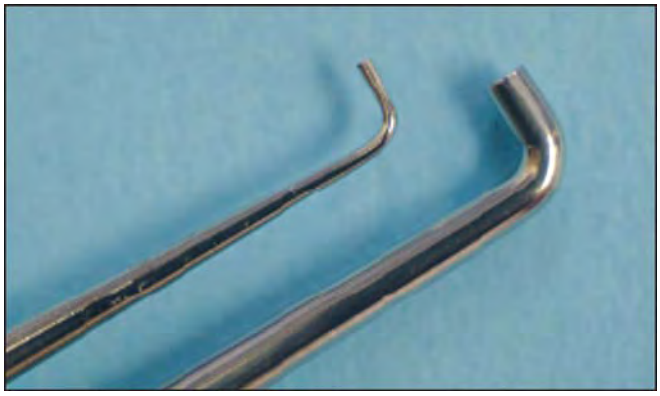
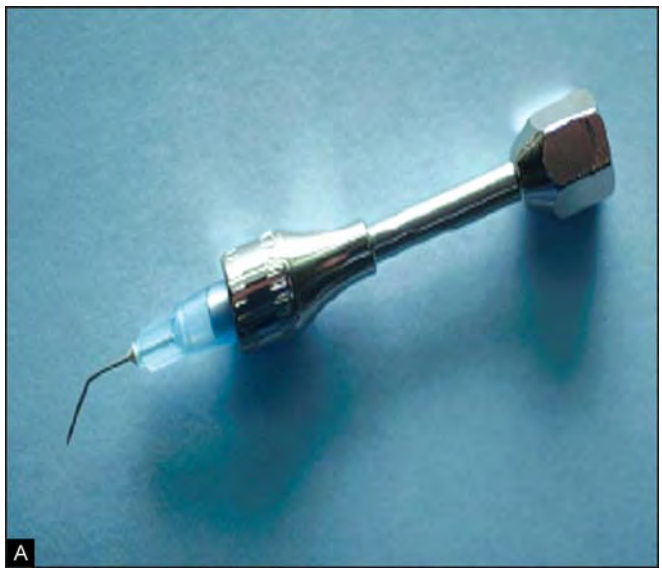
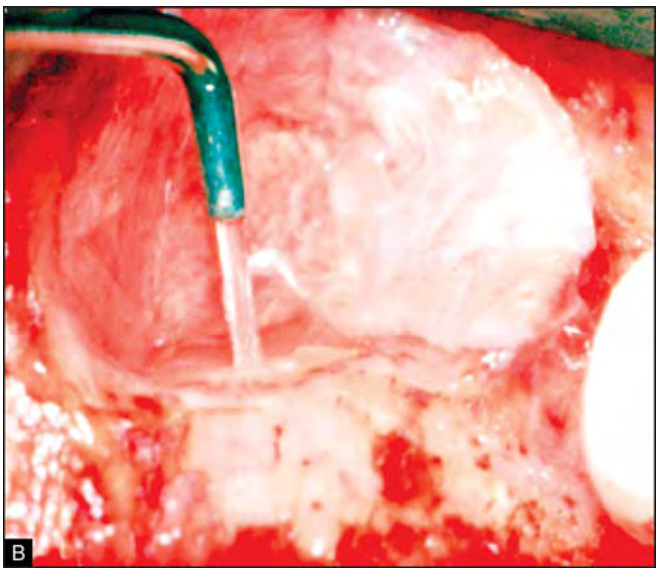


Fig. 18.14: Comparison of a micro plugger with the normal one





Figs 18.15A and B: Stropko irrigator

isthmuses, and tissue remnants are more easily seen when the cut surfaces are thoroughly rinsed and desiccated.

ENDODONTIC SURGERY PROCEDURE

Endodontic surgery has now evolved into endodontic microsurgery. By using state-of-the-art equipment, instruments, and materials that match biological concepts with clinical practice, microsurgical approaches produce predictable outcomes in the healing of lesions of endodontic origin. In this review we attempted to provide the most current concepts, techniques, instruments and materials with the aim of demonstrating how far we have come. Our ultimate goal is to assertively teach the future generation of graduate students and also train our colleagues to incorporate these techniques and concepts into everyday practice.

SOFT TISSUE MANAGEMENT

A flap is defined as a section of gingiva and/or mucosa surgically elevated from the underlying tissues to provide visibility and access to the bone and root surface.

The two major components of surgical access are visual and manipulative. Visual access enables the endodontist to view the entire surgical field in entire. Manipulative access helps the surgeon to carry all the surgical steps without hindrance.

Fig. 18.16: Scalpel blades for surgical incisions. Micro-surgical blade, No. 15C, No. 15, No. 12, No. 11

Principles and Guidelines for Flap Design (Fig. 18.16)

Irrespective of the design of the surgical flap, there are a number of principles and guidelines that apply to the location and extent of incisions. The adherence to these principles and guidelines will ensure that the flapped soft tissues will fit snugly in their original position and will properly cover the osseous wound site and provide an adequate vascular bed for healing:

1. Avoid horizontal and severely angled vertical incisions.
2. Avoid incisions over radicular eminences.
3. Incisions should be placed and flaps repositioned over solid bone.
4. Avoid incisions across major muscle attachments.
5. Tissue retractor should rest on solid bone.
6. Extent of the horizontal incision should be adequate to provide visual and operative access with minimal soft-tissue trauma.
7. The junction of the horizontal sulcular and vertical incisions should either include or exclude the involved interdental papilla.
8. The flap should include the complete mucoperiosteum (full thickness).

When designing a tissue flap, various modes of incision can be selected. Including horizontal, sulcular, submarginal, and vertical releasing incisions. The tissue flap in its entirety can be a full-thickness or a combination of a full- and a split-thickness flap. While many designs have been suggested over the years, some have become obsolete and new techniques have emerged. The main goal behind designing a flap is to achieve healing by primary intention. This goal can be obtained, firstly, by using a complete and sharp incision of the tissues, secondly, by avoiding tearing and trauma to the tissue during elevation, and, finally, by preventing drying of tissue remnants on the root surface and drying of the reflected tissues during the procedure.

Semilunar Flap (one horizontal component—mucogingival)

A semilunar flap consists of a straight or curved horizontal incision in the alveolar mucosa of the apical area, placed all the way to the bone. Numerous disadvantages have made this flap design obsolete. The semilunar flap will only provide limited access to the apical area. It will sever a maximum of blood

vessels by cutting horizontally. Placing the line of incision over the bony defect means that the wound cannot be closed over sound bone. Oral tissue at the apical level consists of many elastic fibers and muscle attachments, both of which exert pulling forces on re-approximated surgical wound margins. This retractive force will not only make suturing difficult, but will result in a constant tension on the flap, poor alignment of wound edges, gap formation and impaired healing.

Triangular Flap (1 vertical + 1 horizontal) (Fig. 18.17)

The triangular flap design comprises a horizontal incision extending to several teeth mesial and distal of the involved tooth and one vertical-releasing incision, usually placed at the mesial end of the prospective flap.

A triangular flap exposes marginal and midsections of the root. Apical areas are generally difficult to reach without pulling extensively on the flap. If the access is too limited, the triangular flap can easily be converted into a rectangular flap by placing an additional releasing incision at the distal end of the horizontal incision.

The triangular flap is mainly indicated for treatment of cervical resorptions, perforations, and resections of short roots.

Advantages

- Minimal disruption of the vascular blood supply to the reflected tissues
- Easy repositioning at wound closure

Drawback

- There is a risk of recession due to the marginal line of incision.
- Cannot be used in maxillary canine region due to long roots and mandibular anterior region due to lingual inclination of roots.

Rectangular and Trapezoidal Flap (Fig. 18.18)

Rectangular and trapezoidal flaps are a continuation of the triangular design by adding a second vertical incision on the distal end of the flap. The difference between the rectangular and trapezoidal version is the degree of divergence of the vertical incisions.

Blood vessels run roughly parallel to the long axis of the teeth. So, the vertical incision should be placed parallel to the root. This favors the rectangular flap. On the other hand, the blood supply and survival of the mobilized tissue appeared to be the best when the base is broader than the proximal end of the flap. However, the unreflected tissue loses the greater part of its blood supply in broad-based flaps. For this reason, the vertical incisions should never be placed converging; rather, the flap width should be extended one or two teeth mesially or distally to the tooth involved. Blood supply to the proximal end seems to be least affected if the ratio of length to width of the parallel pedicle flap equaled 2:1.

In prosthetic restorations involving subgingivally placed crown margins a postoperative sequel can be recession, leading to an esthetically compromising exposure of the crown margins.

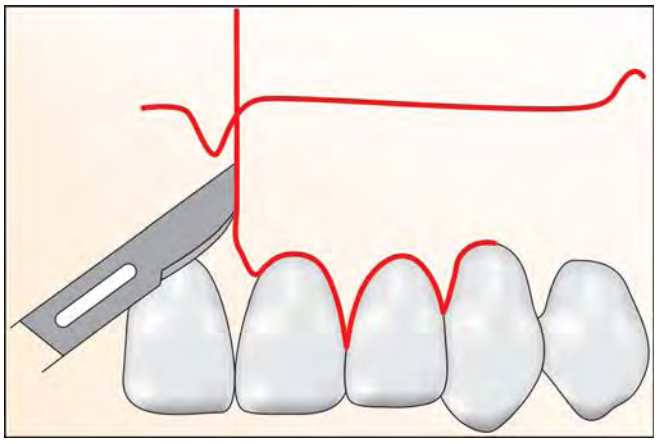


Fig. 18.17: Triangular flap

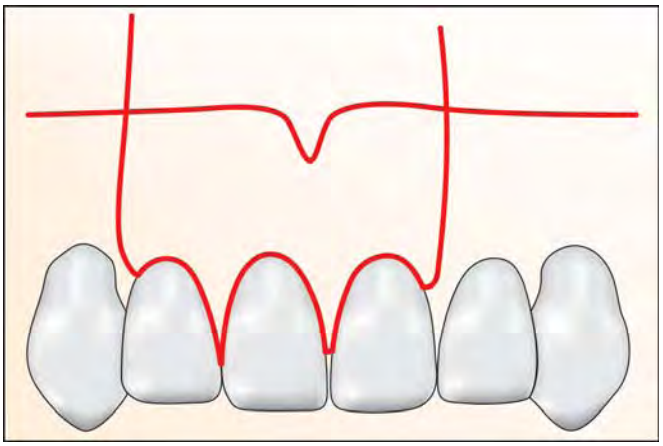


Fig. 18.18: Rectangular flap

Advantages

- Increased visibility, good access especially for lateral root repairs and long roots.
- Simultaneous periodontal surgery can be done.

Disadvantages

- Soft tissue clefting
- Pocket formation if a dehiscence is uncovered
- Elevation is more difficult.
- Involving the marginal gingiva can lead to crestal bone loss.

This flap design is mainly indicated for maxillary canine region and mandibular anteriors.

Submarginal Flap (2 vertical + 1 horizontal - mucogingival) (Fig. 18.19)

The submarginal flap design also referred to as an Ochsenbein-Luebke flap is similar to the rectangular flap, with the difference that the horizontal incision is placed within the attached gingiva. The two vertical incisions are connected by a scalloped horizontal incision, performed roughly parallel to the marginal contour of the gingiva. The submarginal incision should only be used when there is a broad zone of attached gingiva with a minimum of 2 mm, leaving a sufficient amount of marginal attached gingiva in place. It is important to avoid deprivation of blood supply to this unreflected tissue and its necrosis. Such a tissue breakdown will lead to a major recession with poor esthetic result.

When properly planned and performed, the submarginal flap will leave the marginal gingiva untouched and does not expose restoration margins.

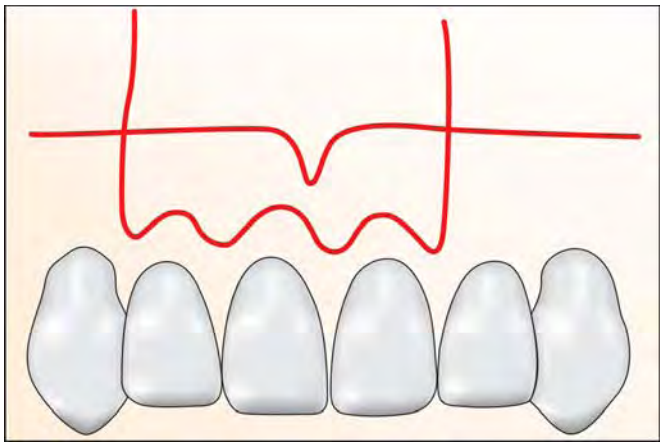


Fig. 18.19: Submarginal flap

The crestal bone is not denuded, preventing potential attachment loss observed with marginal flaps.

Advantages

- Provides good access.
- Does not involve marginal gingival, so crestal bone loss is not seen.

This flap is indicated in presence of prosthetic crowns and existing nonpathogenic dehiscence is avoided.

Disadvantages

- Possible scar tissue formation.
- Risk of postoperative infection. If the incision is in the vicinity of underlying apical lesion or surgical bony access.

Papilla-base Flap (2 vertical + 3 horizontal - sulcular +mucogingival)

Interdental papilla is usually lost due to normal intrasulcular incision. Reconstruction of lost interdental papilla is one of the biggest challenges in periodontal reconstructive surgeries. Loss of interdental papilla can lead to esthetic and phonetic problems. So Velvart introduced this flap design, which prevents the loss of interdental papilla.

It consists of 2 vertical incisions connected by the papilla base incision and intrasulcular incision. This flap requires two different incisions at the base of the papilla.

1. First a shallow incision of 1.5 mm depth is placed on the lower third of the papilla in a slight curved line going from one side of papilla to the other.
2. Second incision is placed at the base of first incision and scalpel subsequently inclined apically, parallel to the long axis of tooth aiming at the crestal bone. This creates a split thickness flap in the apical third of the flap. From that point the flap is elevated as a full thickness mucoperiosteal flap.

Disadvantages

1. Two different incisions are needed to achieve good healing which makes the flap design technique - sensitive.
2. Proper attention should be given not to undermine the flap and make it thin, which leads to difficulty in handling the flap.

3. More number of sutures are needed.
4. Even though no interdental papillary recession is not present; there is mild recession in the cervical area of the flap.

Palatal Flaps

Wustrow described a flap similar to the triangular flap of modern day. A horizontal non-scalloped incision was placed few millimeters below the marginal gingiva and vertical incision towards the midline.

Palatal Flap by Wassmund

Wassmund described a rectangular flap with two horizontal incisions, one along the gingival crevice of tooth and one vertical incision made just before up to the midline, then the other horizontal incision parallel to the first one along the midline extending backward.

Palatal Flap by Wilger and Partsch

They described a semilunar shaped flap that is placed only in the attached gingiva without involving the marginal gingiva. The base of the flap should face the midline.

Palatal Flap According to Fischer

He described a rectangular flap with two nonscalloped horizontal incisions parallel to each other made in attached gingiva and a vertical incision connecting these two.

Nowadays the only two flap designs indicated for palatal surgery are triangular and horizontal designs. Palatal surgical approach is limited only to posterior teeth and contraindicated in anterior teeth, which should be ideally accessed from buccal side. The vertical releasing incision of the triangular flap extends from the marginal gingiva mesial to the first premolar to a point near the palatal midline and is joined by a horizontal intrasulcular incision, which extends distally as far as to provide access.

HARD TISSUE MANAGEMENT

Following adequate tissue incision, reflection and retraction to expose the surgical site, the next stages of periradicular surgery consist of osseous access through the cortical bone, if still intact, and subsequent removal of any soft tissue lesion surrounding the apical and/or lateral aspects of the associated root to provide unimpeded access to these sites (Figs 18.20A to D). The soft tissue lesion may on occasions encapsulate foreign material that may perpetuate the lesion if left in situ. Any excised lesion should be sent for histopathologic examination to confirm the clinical diagnosis and exclude other pathoses.

Osteotomy

Osteotomy involves removal of cortical and cancellous bone to gain direct access to the apical portion, and the lateral aspects if necessary, of the root or roots of a tooth where periradicular periodontitis is present. There may be fenestration of the root tip through the buccal cortical plate, thus providing instant access. The operator may find a periradicular soft tissue lesion that has perforated the cortical plate, in which case curettage of the lesion permits access to the root either without bone removal or minimal extension of the

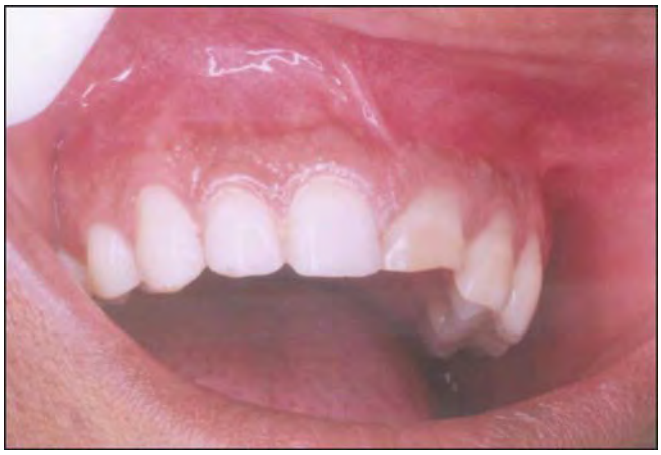


Fig. 18.20A: Preoperative

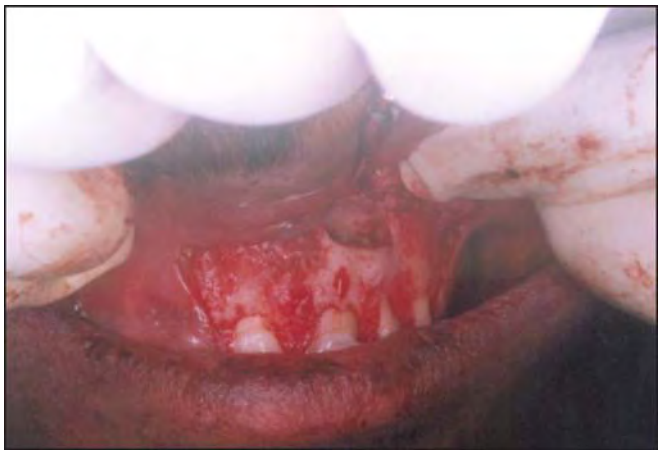


Fig. 18.20B: Flap reflection

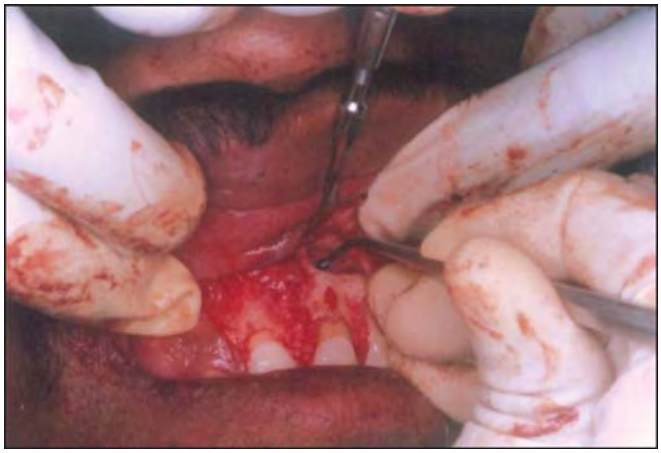


Fig. 18.20C: Osteotomy

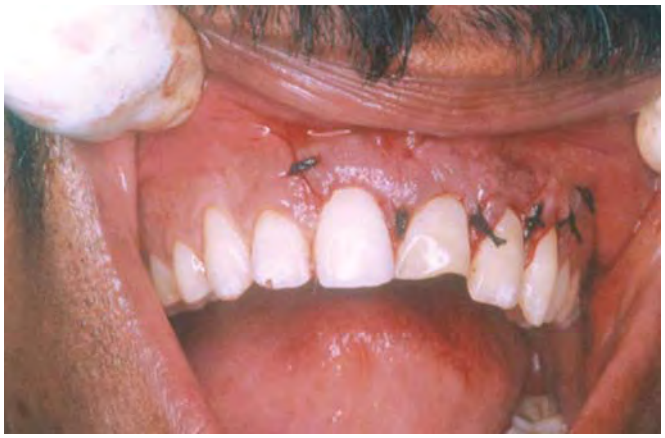


Fig. 18.20D: Wound closure

borders of the defect for improved access. Frequently, however, there will be an intact cortical plate that requires removal to expose the surgical site. This is achieved routinely by using rotary instruments.

Effect of Heat

Several studies have confirmed that irreversible damage to bone occurred when it was heated to above 56°C and that this temperature was easily exceeded during bone cutting.

Cutting Speed

Previously low speed conventional handpieces were used. Recently introduced high-speed air rotor handpieces are used with coolant. Studies concluded that high-speed handpieces were responsible for less injury. Healing with high speed handpiece is better than low speed conventional handpieces.

Moss and Costich et al commented that light pressure is needed when using high-speed handpieces to cut bone, Reduced time is involved in the procedure and there is improved patient acceptance clinically.

The main drawback to the use of high-speed handpieces in surgical endodontics is the risk of surgical emphysema from the air/water spray directed at the cutting site.

The Impact-Air 45 handpiece was introduced to prevent such an occurrence by providing a coolant - only stream directed at the bur tip and exhausting air away from the cutting site (Fig. 18.21). This handpiece head is angled at 45° to the shaft of the instrument to facilitate access to impacted third molars. This has proven to be a great advantage in surgical endodontics performed with the use of a microscope, as the head can be angled in such a way that the entire cutting portion of the bur is visible to the operator.

Coolant

Water or saline coolants applied directly to the cutting surface of a bur in contact with bone will reduce the temperature rise considerably and limit or prevent permanent damage. Several researchers have reported that coolant expressed from water/air syringes and high-speed handpieces are found to have very high colony-forming unit (CFU) count of microorganisms. The site itself, of course, is not sterile, but contaminated with oral bacteria present in the saliva. The recommended alternative involves the assistant directing sterile coolant from a syringe onto the contact area of bur and bone, but this is difficult to achieve if the operating site is in the posterior portion of the arch.

Recent research has shown, fortunately, that there is now the opportunity to lower the CFU counts in dental unit waterlines very significantly, notably by

Fig. 18.21: Impact-Air 45 handpiece

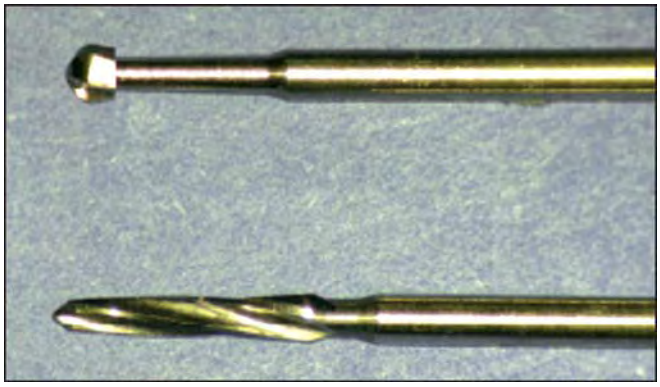


Fig. 18.22: Round and fissure burs

the use of electrochemically activated, or super-oxidized, water. Other chemical systems have also been advocated to achieve the same goal of removing the bacteria present in the biofilm present on the inner walls of dental unit tubing.

Bur Design (Fig. 18.22)

It was noted that round burs, in particular the No. 6 round bur, caused smaller zones of aseptic necrosis than fissure burs, Bur design for surgical use subsequently concentrated on round, steel burs with less flutes that minimize clogging with bone chips and coagulated debris and reduce vibration. Light "brush strokes" with short, multiple periods of osseous cutting will maximize cutting efficiency and minimize the generation of frictional heat.

A round bur is, however, an unsatisfactory design to resect a root tip and provide a uniplanar surface. An alternative to a round bur is the Lindemann H151 (Brasseler USA, Savannah, GA, USA), a tapered steel surgical bur recommended by several authors. It has a widely spaced flute design similar to a surgical round bur, but will produce an acceptable surface of the root tip during resection of the apex, and thus may be used conveniently for both functions.

Proximity to the Anatomic Structures

The area of possible surgical trauma relate to the damage to the maxillary sinus and the various neurovascular bundles. The structures mainly at risk are the inferior alveolar and mental nerve bundles, greater palatine neurovascular bundle, the floor of the nose and the inferior orbital region.

More detailed information can be gained from relevant radiographs of the site. Preoperative periapical radiographs taken using paralleling technique is a pre-requisite to any surgical procedure.

The tooth length may then be measured on the radiograph and will give a good approximation within a couple of millimeters of the total tooth length.

A hand instrument of known length, such as an appropriately long pocket measuring probe, may be placed over the tooth and the likely position of the root apex estimated.

Where the tooth to be treated is multirooted, or the operator suspects there may be a single root with more than one canal present, additional views from an altered horizontal angulation of the tube-head to the mesial or distal, should be exposed. One additional angled view would be the minimum, but for maxillary posterior teeth, both mesial and distal views are considered necessary to gain the maximum information.

Technique of Bone Removal

Following reflection and retraction of the mucoperiosteal flap, surgical access must be made through the cortical bone to the roots of the teeth. Where cortical bone is thin, as in the maxilla, a large periradicular lesion may result in the loss of buccal or labial cortical plate, or if a natural root fenestration is present, the tooth root may be visible through the cortical plate. In other cases, the cortical bone may be very thin, and probing with a small sharp curette will allow penetration of the cortical plate.

When the cortical plate is intact, another method to locate the root apex is to first locate the body of the root substantially coronal to the apex where the bone covering the root is thinner. Once the root has been located and identified, the bone covering the root is slowly and carefully removed with light brush strokes, working in an apical direction until the root apex is identified.

Barnes identified four ways in which the root surface can be distinguished from the surrounding osseous tissue:

1. Root structure generally has a yellowish color,
2. Roots do not bleed when probed,
3. Root texture is smooth and hard as opposed to the granular and porous nature of bone.

4. The root is surrounded by the periodontal ligament.

Under some clinical conditions, however, the root may be very difficult to distinguish from the surrounding osseous tissue. Some authors advocate the use of methylene blue dye to aid in the identification of the periodontal ligament. A small amount of the dye is painted on the area in question and left for 1 to 2 minutes. When the dye is washed off with saline, the periodontal ligament will be stained with the dye, making it easier to identify the location of the root.

The other factor that will determine the outline of the osteotomy is the size and position of any soft tissue lesion surrounding the root tip or lateral opening from the root canal system. The osteotomy should be large enough to allow access to the full extent of the lesion, while retaining as much bone as possible, particularly cervical to the lesion itself. A bridge of healthy cortical plate between the gingival margin and the osteotomy is associated with a more successful outcome. Indeed the prognosis is significantly poorer if no buccal bone is present over the root tissue.

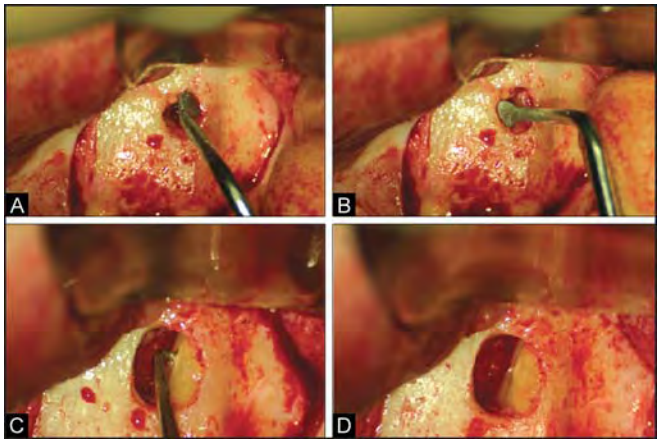
PERIRADICULAR CURETTAGE (FIGS 18.23A TO D)

Once the root and the root apex have been identified and the surgical window through the bone has been properly established, the infected tissue should be removed from the periradicular bony lesion. This removal of periradicular inflammatory tissue is best accomplished by using the various sizes and shapes of sharp surgical bone curettes and angled periodontal curettes. The choice of specific curettes depends upon operator ability. It is advisable, however, to have a wide assortment of curettes available in the sterile surgical pack to use should the need arise (Figs 18.24A to C).

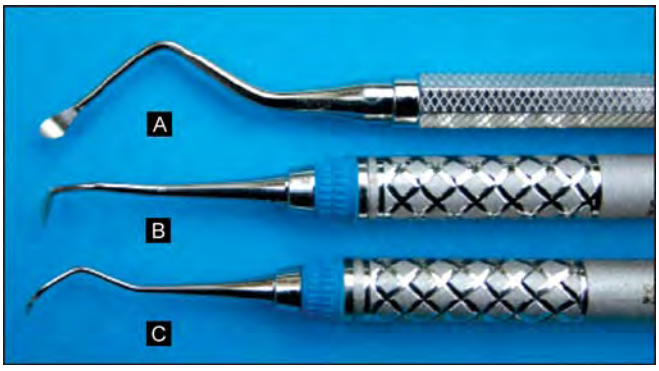
Before proceeding with periradicular curettage, it is advisable to inject a local anesthetic solution containing a vasoconstrictor into the soft-tissue mass. This will reduce the possibility of discomfort to the patient during the débridement process and will also serve as hemorrhage control at the surgical site.

Curettage of the inflammatory soft tissue will be facilitated if the tissue mass can be removed in one piece. Penetration of the soft-tissue mass with a curette will result in increased hemorrhage and shredding the tissue will result in more difficult removal. To accomplish removal of the entire tissue mass, the largest bone curette, consistent with the size of the lesion, is placed between the soft-tissue mass and the lateral wall of the bony crypt with the concave surface of the curette facing the bone. Pressure should be applied against the bone as the curette is inserted between the soft-tissue mass and the bone around the lateral margins of the lesion. Once the soft tissue has been freed along the periphery of the lesion, the bone curette should be turned with the concave portion toward the soft tissue and used in a scraping fashion to free the tissue from the deep walls of the bony crypt.

Once the tissue has been detached from the walls of the crypt, its removal can be facilitated by grasping it with a pair of tissue forceps. The tissue should be immediately placed in a bottle containing 10 percent buffered formalin solution for transportation to the pathology laboratory. All soft tissue removed during



Figs 18.23A to D: (A, B) Bone curette positioned so convex surface faces soft tissue lesion, and the concave surface faces the bone walls of the crypt. (C) Lesion removed and (D) perforation located



Figs 18.24A to C: Instrumentation for curettage. (A) Lucas 86 bone curette. (B) 34/35 Jaquette scaler. (C) Colombia13/14 periodontal curette

periradicular curettage should be sent for histopathologic examination to ensure that no potentially serious pathologic condition exists.

According to Fish, there is a considerable amount of reparative tissue in periradicular lesions. Although it has been advocated for many years that all the soft tissue adjacent to the root be removed during periradicular surgery, in theory and practice this may not be necessary. This is especially true in cases where the lesion invades critical anatomic areas and structures such as the maxillary sinus, nasal cavity, mandibular canal, or adjacent vital teeth. Curettage of soft tissue in these and other critical anatomic areas should be avoided.

Size and Length of the Resected Root Face

Morfis et al and Kim et al have determined that the majority of unfilled lateral canals and other aspects of accessory canal anatomy are located in the apical 3 mm of the root. Thus, 3-4 mm of the apical portion of the root should be clearly exposed, at least to the buccal, mesial and distal. Following resection of the required 3 mm of root tip, there should still be good visibility of the resected root surface for the next stage of the procedure.

Gilheany et al proposed that the depth of the root-end preparation should be at least 3 mm. As a result, most root-end preparation tips, whether ultrasonic or sonic, are 3 mm in length. The osteotomy should therefore be large enough to allow such a tip to be positioned inside the crypt and engage the exposed canal in the resected root face in the long axis of the root, while the surgeon has good unimpaired visual access to the site. If osseous access has already been made to expose 3-4 mm of the root tip, there is no firm requirement to make the margins of the osteotomy larger than this, as the root-end preparation tip should fit without interference.

The dramatic increase in light and magnification as the advent of the surgical operating microscope (SOM) for use in endodontic apical surgery has caused a renewed examination of the rationale, indications, techniques, instrumentation, and materials for root end procedures. Additional research and increased use of the SOM in endodontic surgery have elucidated many shortcomings of previous techniques.

Root End Resection—The Bevel

When the apical end of a root is removed, the remaining surface of the root is described as having been 'bevelled.' The amount and degree of the resected bevel is very important. The overall crown/ root ratio, presence of posts or other obstacles, root anatomy, remaining crestal bone, and the periodontal status of the tooth must be considered.

Traditionally a bevel of 20-45° buccolingual incline was given. In such cases more of the palatal or lingual aspect of the root will be left untreated (Fig. 18.25). This situation occurs when the surgeon is trying to be conservative in order to maintain a more favorable crown/root ratio. Because 98 percent of apical canal anomalies and 93 percent of lateral canals system ramifications occur in the apical 3 mm, it is essential that at least 3 mm of the root end is removed.

Long bevels require the removal of an excessive amount of root structure to include the lingual, or palatal 3 mm of the root apex. If the bevel is closer to 0°, more root structure can be conserved, improving the crown/root ratio while meeting the objective of removing the vast majority of apical ramifications.

The long bevel creates a spatial disorientation that leads to difficulty in visualizing true long axis of the canal system. This may lead the subsequent root-end preparation (REP) away from the long axis of the canal. Failure to visualize long axis of the root may lead to

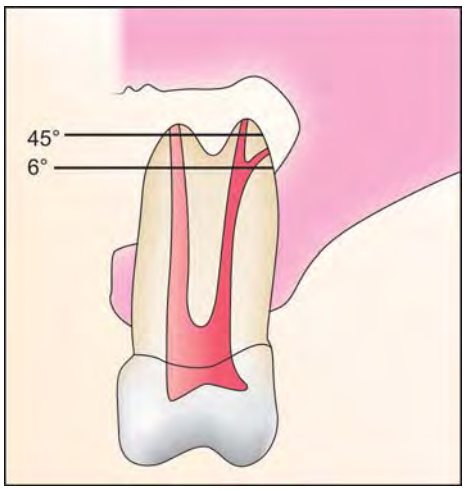


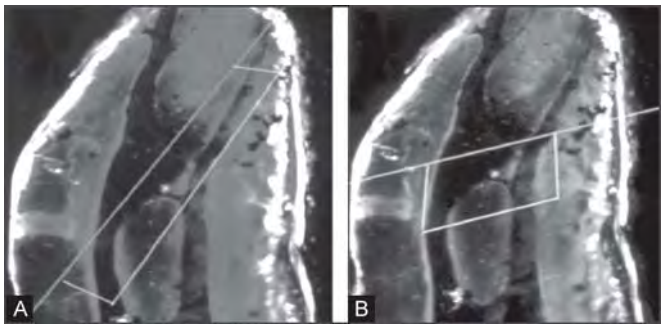
Fig. 18.25: The 'long' bevel (45°) removes more root structure and increases the probability of overlooking important lingual anatomy. The 'shorter' bevel (6°) conserves rootstructure, maintains a better crown/root ratio, and increases the ability to visualize important lingual anatomy

perforations to the lingual, or palatal side. Another consideration for the 0° bevel is that the cavo-surface marginal dimensions of the preparation will be decreased, therefore allowing an easier and more predictable seal. Knowledge of root anatomy is especially important when there are more than two canals in one root.

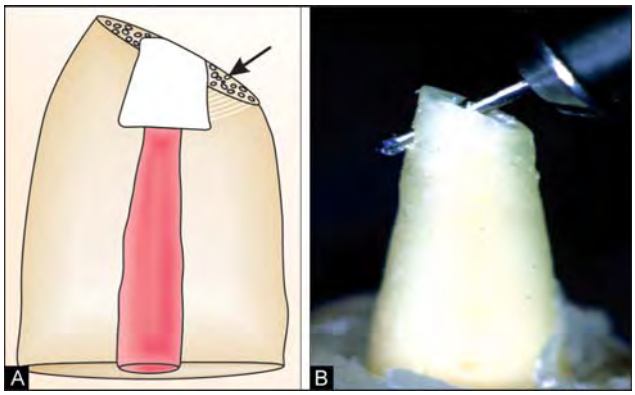
Ideally, the short bevel (0°) is as perpendicular to the long axis of the tooth as possible in order to predictably achieve several important criteria:

1. Conservation of root length—When a long bevel (20-45°) is made, more tooth structure has to be removed in order to expose the anatomical apex of the tooth. With a long bevel, an inordinate amount of root structure would have to be removed in order to include the entire apical 3 mm.
2. Less chance of missing lingual anatomy—The short bevel allows inclusion of lingual anatomy with less reduction. With the long bevel, there is a decreased probability of encroachment on the lingual root surface.
3. A shorter cavo-surface margin (Figs 18.26A and B)—If multiple canals are present, the distance between them will increase as the angle of the bevel increases. As it is recommended that the isthmus also be prepared, a shorter bevel allows for a shorter cavo-surface margin length in the completed REP.
4. Less chance of an incomplete resection—The shorter bevel makes it easier for the operator to resect the root end completely and not leave a 'lingual cusp,' or incomplete resection.
5. Easier to detect multiple or aberrant canals—When the short bevel is prepared, more lingual anatomy can be accessed.
6. Less exposed dentinal tubules (Figs 18.27A and B) - As the dentinal tubules are more perpendicularly oriented to the long axis of the tooth, the short bevel will expose fewer tubules. The long bevel opens more tubules to be exposed to the environment, which can allow more micro-leakage over a period of time.
7. Easier to maintain root end preparations within the long axis—Instrumentation of the root end preparations should be kept within the long axis of the tooth to avoid unnecessary or excess removal of radicular dentin. The longer the bevel, the more difficult it is to envision and maintain within the long axis of the tooth.
8. Easier to include the isthmus in the REP if multiple canals are present in a single root—The cleaning and preparation of the isthmus that usually exists between the canals (whether or not it is visible) after the root end bend is very important.
9. When there are multiple canals in a root, isthmus tissue is present 100 percent of the time at the 4 mm level. The short bevel facilitates the isthmus preparation by allowing a better 'mental picture' of the long axis of the tooth.

Ideally, the root-end bevel is kept as short, or as perpendicular to the long axis of the root as practical, to facilitate complete resection and to expose the entire apical canal system. However, after positive identification of the features on the surface of the bevel has been made, it may be necessary to increase the angle of bevel slightly, to achieve better access for instruments, for improved vision, and/or to enhance ergonomics for the patient and clinician.



Figs 18.26A and B: (A) The long bevel has a greater cavo-surface margin length with a greater probability of leakage. (B) The short bevel has a shorter cavo-surface margin length to seal and, therefore, decreases the chances of leakage



Figs 18.27A and B: (A) The long bevel exposes more dentinal tubules at an angle so they are left open to cause possible future contamination, or leakage, to the REF. (B) The long bevel disorients the surgeon, and the tendency for a lingual perforation of the root-end preparation is increased

Instrumentation and Technique

Although many instruments and burs are available to complete the RER and REB, Essentially, there are only three surgical length burs necessary to accomplish the required tasks.

They are (Fig. 18.28):

1. The No 6 or No 8 round bur (SS White, Lakewood, NJ, USA), for osseous access and gross removal of the apex;
2. The Lindemann bone bur (Brasseler USA, Savannah, GA, USA), for rapid hard tissue removal and cutting the initial root bevel.
3. The No 1170 or No 1171 bur (SS White), for refinement of the bevelled surface.

METHYLENE BLUE STAINING (FIG. 18.29)

After complete hemostasis is achieved, the beveled surface is ready for close inspection to be certain that the root end bend has been properly completed. The resected root end is rinsed and dried with an irrigator (Stropko Irrigator). The dried surface is then stained with 1 percent methylene blue for 10-15s and then gently flushed with a sterile solution and dried with an irrigator.

As the methylene blue only discolors organic material, it readily defines the anatomy in and around the resected root end with a deep blue color. If there are any fractures, tissue remnants in the isthmus, or accessory canals present, the staining process will greatly enhance the operator's ability to see them. When used properly, the MBS will delineate the periodontal ligament and the operator can be sure the apex has been completely resected.

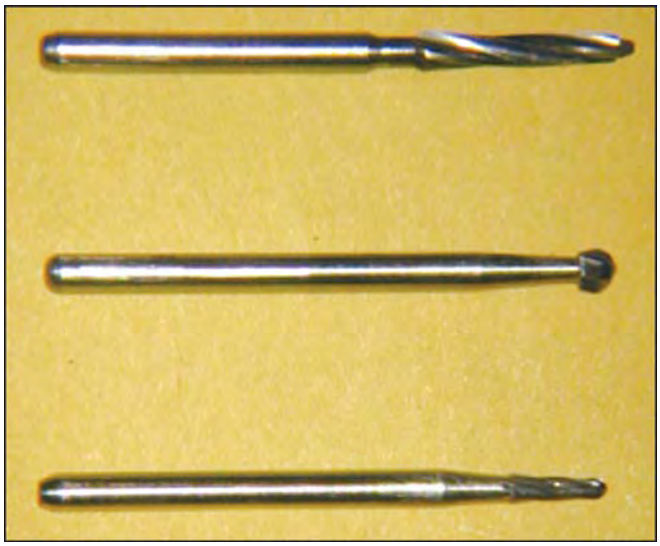


Fig. 18.28: Burs used in RER and REB

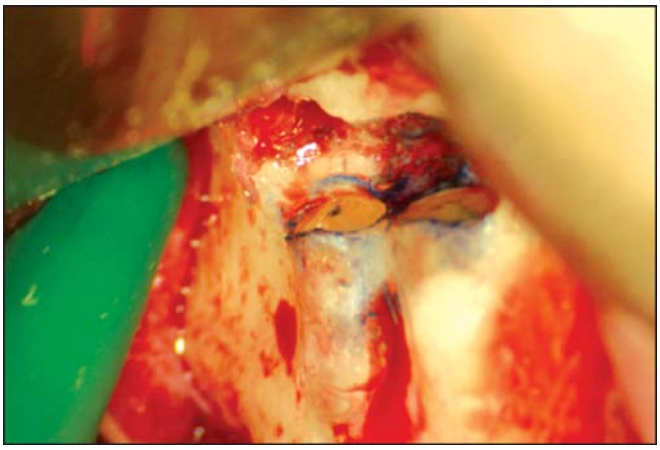


Fig. 18.29: Methylene blue staining of the periodontal ligament and the exposed canals

THE ISTHMUS

An isthmus is a narrow connection between the two root canals which usually contains pulp tissue. It is addressed by different names as corridor (Green 1973), a lateral connection (Pineda-1973) and anastamosis by Vertucci (1984).

This connection may be complete or partial. Isthumi are commonly found approximately 3 mm from the apex.They are found in 15 percent of anterior teeth and premolars. They are found in16 percent at 1mm level and in 52 percent at 6 mm level. Identification of isthmus is very important for the success of surgical procedures.

Kim identified 5 types of isthmus on beveled root surface:

- *Type I:* Incomplete isthmus. It is a faint communication between two canals.
- *Type II:* Complete isthmus. Two canals with a definite connection between them.
- *Type III:* Very short complete isthmus between two canals.
- *Type IV:* Complete or incomplete isthmus between three or more canals.
- *Type V:* Two or three canal openings without visible connections.

As a part of root canal, isthmus should be cleaned, shaped and filled as thoroughly as other canal spaces.

Microsurgical techniques enable the clinician to visualize the isthmus and prepare it with ultrasonic instrumentation and fill it with acceptable material.

ROOT END PREPARATION (REP): PROCEDURE

Ultrasonic Root End Preparation

The advent of ultrasonic instrumentation, and the array of angled tips currently available to the operator, it is now possible to prepare a root end preparation that will adequately and predictably accept several different root-end filling root end filling materials. The requirements for a root end preparation include:

- The apical 3 mm of the canal system is thoroughly cleaned and shaped
- The preparation is parallel to, and centered within, the anatomic outline of the pulpal space
- There is adequate retention form for the root end filling material used,
- All isthmus tissue is removed.
- The remaining dentinal walls are not weakened.

The use of any one type of ultrasonic units will allow the operator to complete the root end preparation.

Different equipment used in ultrasonic preparation are:

1. The Satelec P- 5 (Mount Laurel, NJ, USA)
2. EMS MiniEndo (SybronEndo, Orange, CA, USA) (Fig. 18.30)
3. NSK (Brasseler, Savannah,GA, USA)
4. Spartan (Obtura-Spartan, Fenton, MO, USA)

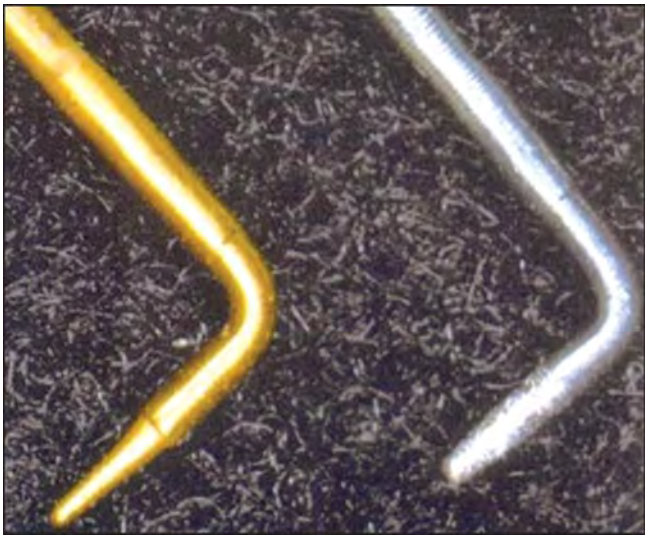


Fig. 18.30: EMS REP tips

These units are currently the most common and all have a good reputation for performance, reliability, and versatility.

There are a multitude of ultrasonic tips to choose from and they come in all shapes and sizes. Most commonly these tips are manufactured from stainless steel with different coatings on the tips.

Type	*Coating*	*Manufacturer*
CT-tips	Plain/diamond coated	Analytic endo
KiS tips	Zirconium nitride coated	Spartan/Obtura
Pro Ultra tips	Ticonium coated	Dentsply /Tulsa Dental
Satelec	Diamond coated	Satelec/Amdent

The first tips made for endodontic apical microsurgery were developed by Garry Carr and are also known as Carr tips (CT series tips. SybronEndo) (Fig. 18.31). They are 0.25 mm in diameter about 1/10th the size of conventional handpiece. They are made of stainless steel are very popular, and still in widespread use today.

Cutting efficiency of plain stainless steel tips is low. To make the cutting more aggressive, some tips have special surface coatings to increase their efficiency. Diamond-coated tips are very efficient and especially useful for removing gutta-percha from the root end preparation. The disadvantages of diamond coated tips include overpreparation and a heavily abraded preparation leading to accumulation of debris, which, if not removed can affect the apical seal of the root end filling. Plain stainless steel tips produce comparatively smoother preparations than diamond coated tips.

The KiS ultrasonic tips (Obtura-Spartan, Fenton, MO, USA) (Fig. 18.32) are the next generation of ultrasonic tips coated with zirconium nitride. These tips are available from KiS no. 1 to 6 for use in different regions.

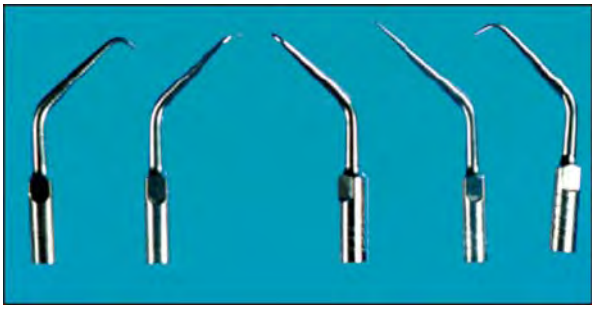


Fig. 18.31: The first ultrasonic tips available—CT tips

Fig. 18.32: The KiS ultrasonic tips

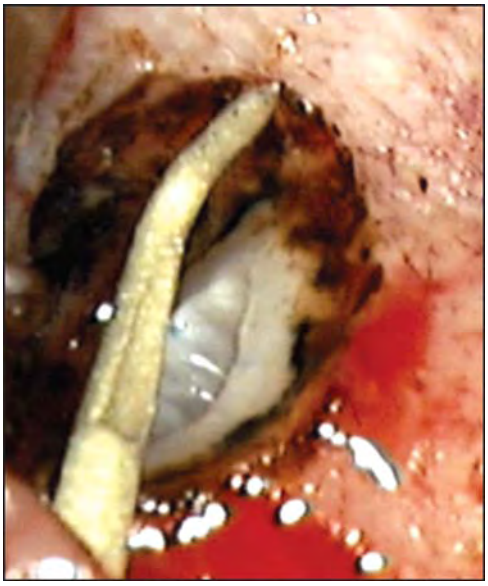


Fig. 18.33: REP using ultrasonic tip

It uses port technology and delivers a constant stream of water aimed directly at the working end of the tip.

Ticonium-coated tips (ProUltra, Dentsply Tulsa Dental, Tulsa, OK, USA) Are also very efficient. Like all tips, they provide excellent vision for the operator during the root end preparation.

The most important consideration in the use of ultrasonics is the pressure exerted during the preparation. They should be used with an extremely light touch. In general, the lighter the touch, the more efficient the cutting efficiency will be (Fig. 18.33).

The correct amount of water is also important. If too much spray is used, visibility and cutting efficiency are both decreased. If too little water is used, the necessary amount of cooling and rinsing of the debris will not occur. This can cause overheating of the root end preparation, microcracks and decreased vision. With the advent of ultrasonic techniques for the preparation of the root end, the use of a rotary hand piece is not advocated for root-end cavity preparation in apical surgery.

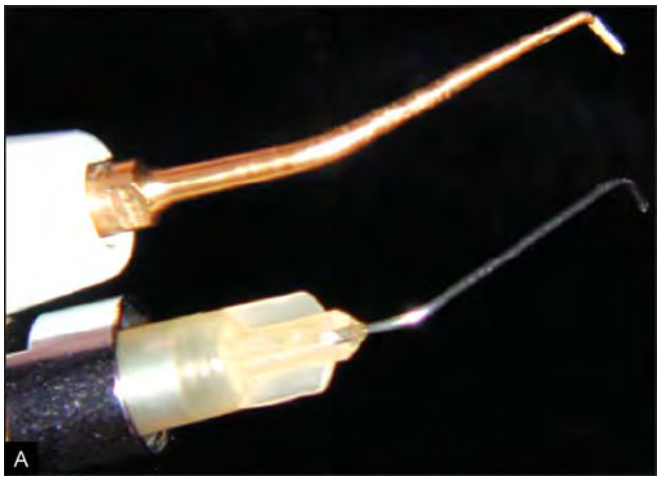
If the canal is large and/or filled with gutta-percha, a diamond-coated anterior KiS tip can be used most effectively. The various left- and right-angled tips are necessary on occasion, but in most cases, the anterior type tips will suffice.

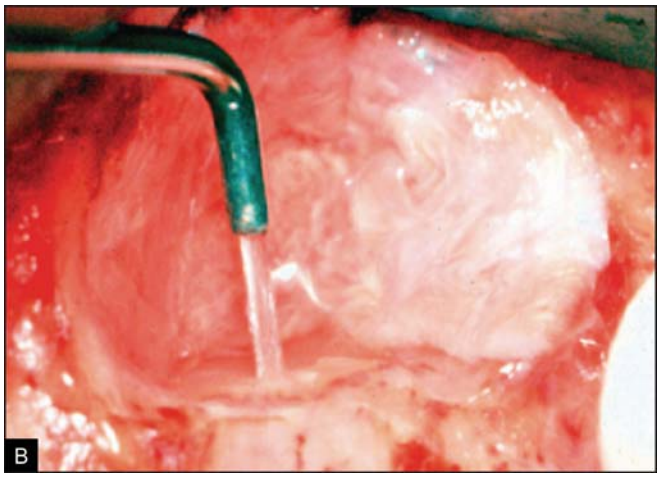
The use of ultrasonic instrumentation is especially useful in the preparation of an isthmus between two canals present in one root. This is a commonly required procedure during apical microsurgery. It is important to routinely prepare the isthmus, whether it is defined by staining, or not, because if the isthmus is just coronal to the beveled surface, post-surgical remodelling of the bevelled root surface may expose the entire canal system to the periradicular tissues. If the non-surgical root canal treatment fails to clean the canal system thoroughly or coronal leakage is present, failure may ensue. A good rule to follow is to always prepare an isthmus when there are two canals in one root.

For the preparation of an isthmus, a CT-X explorer may be used to "scratch" a "tracking groove" between the canals. With the water spray turned off, a CT-1 tip or any sharp, pointed ultrasonic tip can be used at low power, to deepen the tracking groove. Not using a water spray allows excellent vision for the creation of the 'tracking groove,' but the groove should only be deepened enough without the water spray to make it more definitive and easy to follow. The water spray should be resumed as soon as possible to allow for appropriate cooling and cleaning of the REP.

If difficulty is experienced when trying to establish a tracking groove, the 'dot technique' may be used. With the CT-1 tip inactivated and no water spray, place the pointed tip exactly where desired and just lightly 'tap' the rheostat for an instant. The process is repeated again, and again, as many times as necessary, until there are a series of "dots" created on the isthmus. It is then a simple matter of connecting the dots to create the initial "tracking groove".

The accuracy of cutting is then maintained and the probability of 'slipping off' a small, or thin, bevelled surface is eliminated. After the groove is deep enough to guide the tip, the water spray is turned back on and the preparation is deepened to 3 mm while using a similar small, pointed tip. Then, a larger and more efficient coated tip is used to finish the walls and flatten out the floor of the REP to the desired finish. A clean and dry apical root-end cavity preparation is essential for good visibility when using the SOM.





Figs 18.34A and B: The Stropko irrigator can direct a precise stream of water or air into the root-end preparation (REP), enhancing the inspection process

Throughout the process, and after completion of the REP, the cavity should be rinsed and dried with a small irrigator/aspiration tip if possible (Figs 18.34A and B). If a 25- or 27-gauge-irrigating needle has been 'pre-bent' to a similar shape as the ultrasonic tip used for the REP, the ergonomics of using the irrigator will be more efficient.

Subsequently, the cavity is inspected using various levels of magnification and sizes of micromirrors to confirm that the preparation is within the long axis of the canal system and all debris has been removed. As an alternative, some surgeons choose to use small segments of paper points to dry the cavity; however, this may leave particles of paper in the preparation or may fail to provide a thorough drying in all dimensions.

Smear layer removal can be effectively removed by etching with either 10 percent citric acid gel, 17 percent EDTA, MTAD or 35 percent phosphoric acid gel. After etching, the root end preparation is again thoroughly rinsed, dried, and re-examined under varying powers of magnification.

Advantages

- Better apical preparations (parallel walls in the long axis of the root)
- Smaller preparations where depth is more than width, leading to preservation of thickness of root canal wall and reduced microleakage.
- Proper cleaning of isthmus between the exits of apical canals
- Easier access to the root tips
- Lesser strain and fatigue to the operator

The combination of the SOM and ultrasonic tips make previously challenging cases much easier. Apical preparation can be visualized and executed more precisely. By combining magnification and ultrasonics, preparation of the apex can be conservative and can actually be viewed in the axial plane of the root.

Root End Filling (REF)

Once the microsurgical root end resection is complete, the tissues have been retracted and bleeding in the surgical crypt is well managed, the REP is ready to fill.

There are several materials currently available for the REF, each having been used with varying degrees of success.

They include:

- Amalgam,
- IRM (DENTSPLY / Caulk, Milford, DE,USA),
- Super-EBA (S-EBA, Bosworth, Skokie, IL,USA),
- Optibond (Kerr, Orange, CA, USA),
- Geristore(DenMat, Santa Maria, CA, USA),
- Mineral trioxide aggregate (Pro Root MTA, DENTSPLY / Tulsa Dental).

MTA (MINERAL TRIOXIDE AGGREGATE)

MTA has become very popular in endodontic surgical applications. It was developed at Loma Linda University in the 1990s as a root-end filling material. It is a powder that consists of fine hydrophilic particles that set in the presence of moisture. Described for the

first time in the dental literature by Lee et al in 1993, MTA was approved by the FDA in 1998 as a material to seal off pathways of communication between the internal and external environment of the root canal system.

Given the favorable results of MTA as a root-end filling material, its use has been extended to procedures such as pulp capping, pulpotomy, apexification, internal root resorption, and most importantly the sealing of perforations. It is the material of choice in the non-surgical treatment of furcal and radicular strip perforations.

It is commercially available as ProRoot MTA (Dentsply Tulsa Dental, Tulsa, OK, USA) in either the gray or white forms. Recently, a new cement was launched commercially labelled as MTA-Angelus (Angelus Soluc¸o˜es Odontolo´gicas, Londrina, Brazil). Pro-Root-MTA is composed of 75 percent Portland cement, 20 percent bismuth oxide and 5 percent dehydrated calcium sulfate while MTA-Angelus is composed of 80 percent Portland cement and 20 percent bismuth oxide and no calcium sulfate (gypsum). The absence of calcium sulphate may reduce the setting time to 10 min.

MTA may show certain similarities to Portland cement but it cannot be substituted by it. MTA consists of less toxic heavy metals (CU, Mn, Sr), less chromophores (Fe, Mn), less aluminium species and approximately half the amount of gypsum in comparison to Portland cement. Bismuth oxide is also absent from the latter. MTA shows a uniform and smaller particle size, unlike Portland cement which has a wide range of sizes.

Comparison of white and gray MTA indicates that lime (CaO), silica (SiO_2), and bismuth oxide (Bi_2O_3) are the dominant compounds and are present at comparable levels in either of the types. The most significant differences observed were between the concentrations of Al_2O_3, MgO, and especially FeO. The white MTA lacks the aluminoferrite phase that imparts the grey colour to gray MTA. Biologically, gray MTA may prove to be more active as it produces more hydroxyapatite crystals on its surface compared to the white version.

Researches have proved the virtues of this material regarding its sealing capabilities and its favorable biocompatibility. MTA has been shown to have superior sealing qualities when compared with EBA and amalgam. The cellular response to MTA has also been shown to be better than IRM and it stimulates interleukin production, indicating biocompatibility with adjacent cells. One of the most important advantages of MTA is that histological examinations show evidence of tissue regeneration (reformation of bone periodontal ligament and cementum as a functional unit) as opposed to tissue repair (fibrous connective tissue).

Comparing Calcium Hydroxide and MTA as Pulp Capping Agent

In-vitro and in-vivo studies have proven that MTA forms a thin layer of calcific barrier formation after pulp-capping; whereas calcium hydroxide does not result in a continuous calcific barrier formation.

Hence, MTA is superior than calcium hydroxide in this regard.

One of the main disadvantages of MTA is difficulty in handling. The correct powder/water ratio is three parts powder to one part sterile aqueous solution. After mixing for about 30s, the material should exhibit a putty-like consistency. If the mixture is too wet, it acts like wet sand and 'slumps,' but when too dry, it has a 'crumbly' and unmanageable texture, similar to that of dried mud. In either case, when not mixed properly, MTA can be very difficult, if not impossible, to handle.

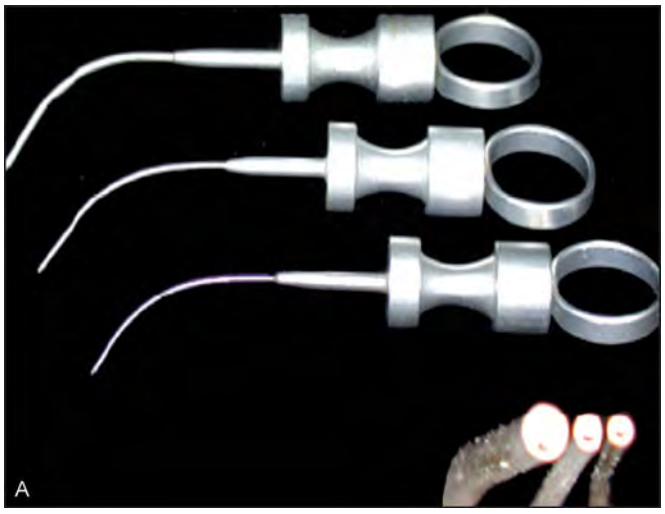
The central problem with MTA is that this material can be difficult to deliver to a small REP. Most clinicians use a syringe or carrier-type device to deliver MTA.

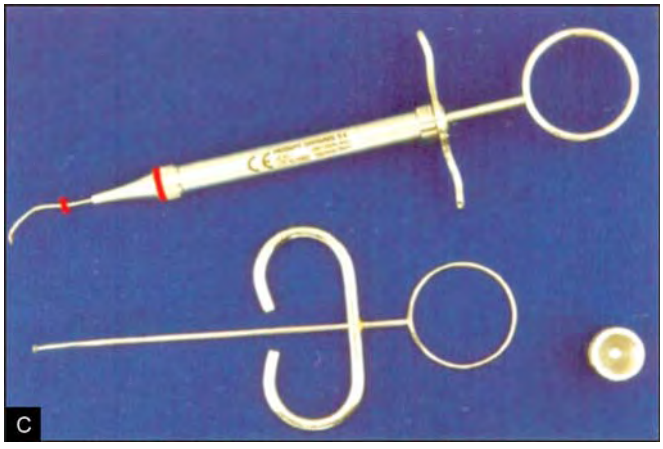
These devices have several limitations:

1. The diameter of the syringe or carrier may be too large for small root preparations.
2. The syringe and carrier devices may not reach surgical areas with difficult access.
3. The syringe and carrier devices deliver large amounts of MTA, resulting in excessive amounts of material being deposited into the field.
4. The syringe devices can clog and become useless if not properly cleaned immediately after every procedure.

Some of the available carriers used to place MTA into the REP include the (Figs 18.35A to C):

- Retrofill AmalgamCarrier (Miltex,York, PA, USA),
- Messing Root Canal Gun(Miltex),
- Dovgan MTA Carriers (Quality Aspirators, Duncanville, TX, USA)

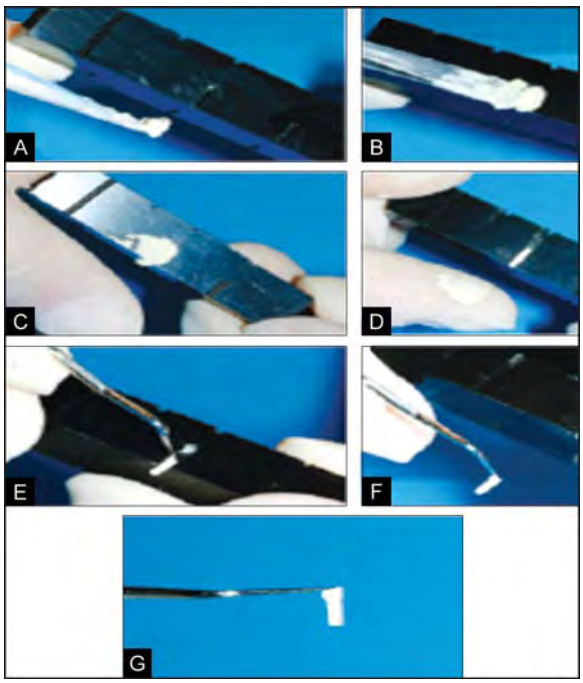




Figs 18.35A to C: MTA carrier systems

- MAP System (PD, Vevey, Switzerland) (Fig. 18.35B),
- Lee MTA Pellet Forming Block (G. Hartzell & Son, Concord,CA, USA)

The Lee MTA Pellet Forming Block (Figs 18.36A to G) is a very simple and efficient device for preparing MTA to be carried to the root end preparation. Properly mixed MTA is simply wiped onto a specially grooved block and the Lee Instrument is used to slide the desired length of MTA out of one of the appropriately sized grooves. The MTA adheres to the tip of the instrument, allowing for easy placement into the REP. With this method of delivery, fewer 'passes' are required to fill the REP adequately. As with any other MTA carrier, use of the Lee Pellet Forming Block requires the correct powder/ water ratio of MTA for ease of use. The mix must be wet enough not to crumble, but dry enough to prevent 'slumping.' Adding or removing water from the mixture obtains



Figs 18.36A to G: MTA to the root-end preparation (REP). (A) The MTA mixed to a 'putty-like' consistency on a spatula is (B) placed onto the appropriate size groove in the Lee MTA block, (C) pressed into the groove with a finger, (D) the surface around the groove is wiped clean with a finger, (E) the desired length of the MTA is selected, (F) to be removed by instrument and (G) carried to the REP in an efficient manner (*Courtesy:* Endodontic Topics)

the desired 'working consistency.' Either a cotton pellet, used dry or moistened with sterile water, or an irrigator, delivering air or water, may be used for this purpose. After the MTA is delivered into the REP, it is 'patted' or 'persuaded' to place with an appropriate plugger type instrument. Compaction, should be avoided while placing this material. If a plugger or small explorer is placed in contact with the MTA, and is gently touched 'non-working end' of the instrument with an activated ultrasonic tip, the material 'flows,' entrapped air is released, and the density of the fill is increased. The radiographic appearance may also improve with 'ultrasonic densification'.

MTA has a 2-3 hour working time, which is more than adequate for apical microsurgery and takes the 'time pressure' out of the procedure. The surface of the MTA is finished by carving away excess material to the level of the resected root end. This is done in a dry field, as the moisture necessary for the final set is derived from blood that fills the surgical crypt once the tissue is repositioned and sutured. MTA is very hydrophilic and requires moisture for the final set. It is necessary to have enough bleeding to be re-established to ensure that the crypt is filled with blood. If necessary, gentle curettement of the surgical crypt will initiate the required hemorrhage. This is the final step in 'crypt management,' or hemostasis, especially when MTA is used as the REF material.

Soft-Tissue Repositioning and Suturing

Once the examination of root-end filling is done and all visible excess is removed, a radiograph should be taken to evaluate the placement of the root-end filling and to check for the presence of any root fragments or excess root-end filling material. Thorough examination of the underside of the flap, in the depth of the fold between the mucoperiosteum and the alveolar bone, should be done before repositioning the flap to remove any debris or foreign material that may be present. The final steps in the periradicular surgical procedures are wound closure and soft-tissue stabilization.

Repositioning and Compression

The elevated mucoperiosteal tissue should be gently replaced to its original position with the incision lines approximated as closely as possible. Using surgical gauze, slightly moistened with sterile saline, gentle but firm pressure should be applied to the flapped tissue for 2 to 3 minutes (5 minutes for palatal tissue) before suturing.

Tissue compression, both before and after suturing, not only enhances intravascular clotting in the severed blood vessels but also approximates the wound edges, especially the dissectional wound. This reduces the possibility of a blood clot forming between the flap and the alveolar bone.

Gut

Collagen is the basic component of plain gut suture material and is derived from sheep or bovine intestines. Gut sutures are absorbable; however, the absorption rate is variable and can take up to 10 days. Chromic gut sutures consist of plain gut that has been treated with chromium trioxide. This results in a delay in the absorption rate. Because retention of sutures beyond a few days is not recommended in endodontic surgery, the use of chromic gut sutures offers no advantage. Also, evidence indicates that plain gut is more biocompatible with oral soft tissues than is chromic gut.

Gut suture material is marketed in sterile packets containing isopropyl alcohol. When removed from the packet; the suture is hard and nonpliable because of its dehydration. Before using, gut sutures should be hydrated by placing them into sterile, distilled water for 3 to 5 minutes. After hydration, the gut suture material will be smooth and pliable with manipulative properties similar to silk.

Collagen

Reconstituted collagen sutures are made from bovine tendon after it has been treated with cyanoacetic acid and then coagulated with acetone and dried. Collagen sutures offer no advantage over gut for endodontic surgery since their absorption rate and tissue response are similar. They are available only in small sizes and used almost exclusively in microsurgery.

Polyglycolic Acid (PGA): Suture material made from fibers of polymerized glycolic acid is absorbable in mammalian tissue. The rate of absorption is about 16 to 20 days. Polyglycolic acid sutures consist of multiple filaments that are braided and share handling characteristics similar to silk.

Polyglactin (PG)

In 1975, Craig and coworkers reported the development of a copolymer of lactic acid and glycolic acid called Polyglactin 910 (90 parts glycolic acid and 10 parts lactic acid). Sutures of polyglactin are absorbable and consist of braided multiple filaments. Their absorption rate is similar to that of polyglycolic acid. They are commercially available as Vicryl. The suture should be removed as early as possible within 2-3 days to prevent food accumulation.

SUTURING

It is important to stabilize the reflected tissue to prevent dislodgment until initial wound healing has taken place. Several authors have reported on studies in animals and humans designed to evaluate the effectiveness of medical grade adhesives, such as cyanoacrylate, for surgical wound closure and to compare them with sutures. Results of these studies have been mixed, and, at this time, their use has not replaced that of sutures for wound closure in endodontic surgery. The purpose of suturing is to approximate the incised tissues and stabilize the flapped mucoperiosteum until reattachment occurs. The placement of sutures in oral tissues, however, creates unique problems.

Sutures are available in many different materials, the most common being synthetic fibers (nylon, polyester, polyglactin, and polyglycolic acid), collagen, gut, and silk.

Sutures are classified by:

1. Absorbency (absorbable or nonabsorbable),
2. Physical design as monofilament, multifilament, twisted, or braided.

The classification of suture size is complicated by the existence of two standards, the United States Pharmacopeia (USP) and the European Pharmacopeia (EP). The USP size is designated by two Arabic numbers, one a 0, separated by a hyphen (3-0, 4-0, 5-0, etc). The higher the first number, the smaller the diameter of the suture material. The EP system is a number that represents the manufacturer's minimum diameter tolerance of the suture in millimeters (1 = 0.10 mm, 1.5 = 0.15 mm, etc).

Silk

Silk sutures are made of protein fibers (fibroin) bound together with biologic glue (sericin), produced by silkworms. Silk sutures are nonabsorbable, multifilamentous, and braided. Advantage is limited to its ease of manipulation. Because of the severe tissue reaction to silk, it is not the suture material of choice for endodontic surgery.

Needle Selection (Figs 18.37A and B)

A surgical needle is necessary for the placement of a suture. The needle must be designed to create minimal trauma during penetration of the tissue. A sharp needle point, small body diameter and the thread swaged at the end are key properties for the least traumatic applications. Needle length is selected

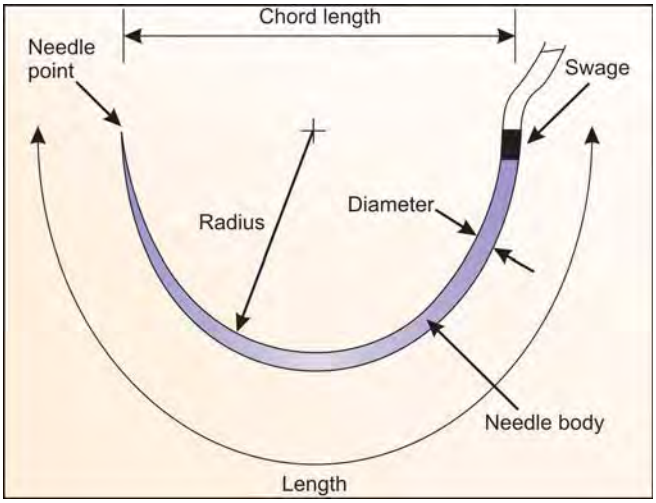


Fig. 18.37A: Schematic drawing of the elements and measurements of a suturing needle

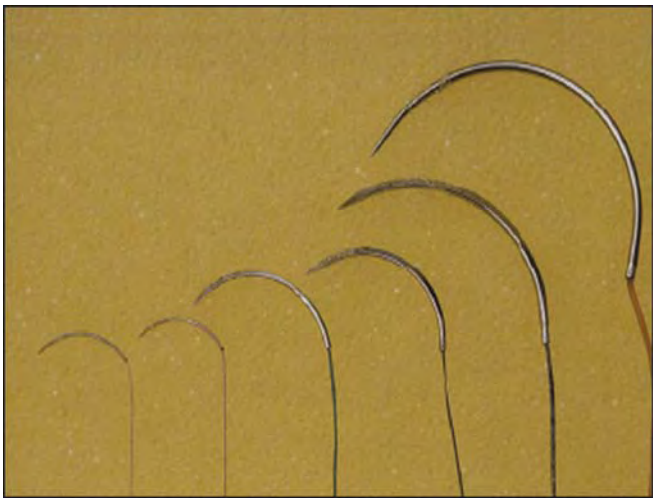


Fig. 18.37B: Various sizes of sutures. Note needle length increase with increased suture size

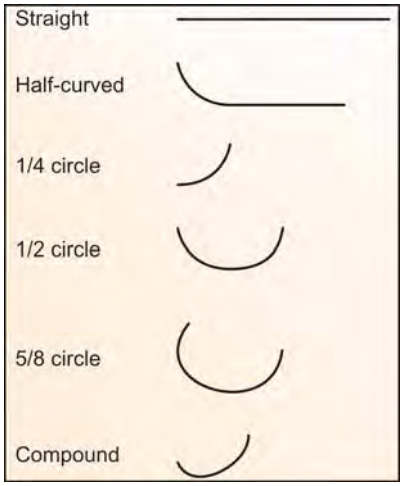


Fig. 18.38: Schematic drawing of various needle shapes used in dental surgery

depending on the site of suture placement. The size of the suture generally correlates with the needle length (Fig. 18.37). When interproximal sutures are needed, needles of 11-13 mm in length are required. Needle shapes are 3/8 circle (the most frequently used shape in dentistry) 1/2 circle and 5/8 circle (Fig. 18.38). Modern microsurgical wound closure requires nonabsorbable suture material in sizes 6-0 to 8-0. As monofilament 6-0 sutures are difficult in knot tying and extremely uncomfortable for the patient because of their stiffness, polyamid, pseudo monofilament (coated multifilament) are recommended (Supramid) These sutures are available with 11 and 13 mm long needles and are ideal for interproximal wound closure. Releasing incisions or partial thickness, split flaps are best closed with monofilament, polypropylene 7-0 or 8-0 sutures. In multilayered flaps, for inner layer closure absorbable, monofilament, polyglactin 7-0 or smaller (coated Vicryls) is recommended.

Suture Techniques

Postoperative recession of gingival and delayed healing are problems that can result from traumatic tissue elevation and suturing techniques. Aesthetically disappointing results are a major concern to the patient and the clinician. Suture materials and knots themselves cause irritation and foreign body reactions, therefore some authors recommend using only minimal numbers of sutures to secure the flap. By choosing microsurgical materials (size 7-0 or 8-0), the number of sutures within a given area can be increased

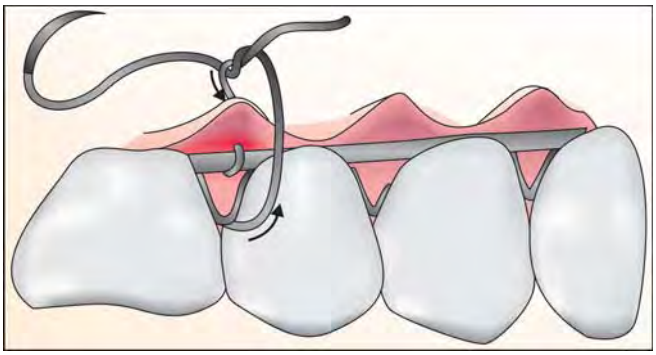


Fig. 18.39: Interdental sutures

without further compromising the blood supply. Handling such materials, however, requires a magnification device and delicate instruments to control their exact manipulation.

Single interrupted suture: The single interrupted suture is used for closure and stabilization of vertical releasing incisions in full mucoperiosteal flaps and horizontal incisions in limited mucoperiosteal flap designs.Suture pattern passes through a single point on either side of the incision.Each suture tied separately and the bite is placed 2-3 mm from flap edge.

Interrupted loop (Interdental) suture (Fig. 18.39): Interdental suture is used to stabilize the horizontal component of full mucoperiosteal flaps. The needle is inserted through the facial interdental papillae, then through the lingual interdental papillae, and then back through the interdental embrasure. It is tied on the buccal or facial surface of the attached gingiva. This suture technique may lead to the inflammation of the fragile interdental tissue and col leading to delayed healing, and possible blunting or formation of a double papillae.

Vertical mattress suture (Fig. 18.40): This technique does not require needle penetration or suture material to pass through tissue involved in the incisional wound. The needle enters and exits the flapped mucoperiosteum some distance apical from the incision line. The suture is passed through the interdental embrasure, towords the lingual gingiva of the adjacent tooth and passed back through the opposite interdental embrasure. The needle then enters and exits the flapped muco-periosteum again, is passed through the embrasure, and, again, lingual to the tooth and through the opposite interdental embrasure to be tied on the buccal surface with a knot.

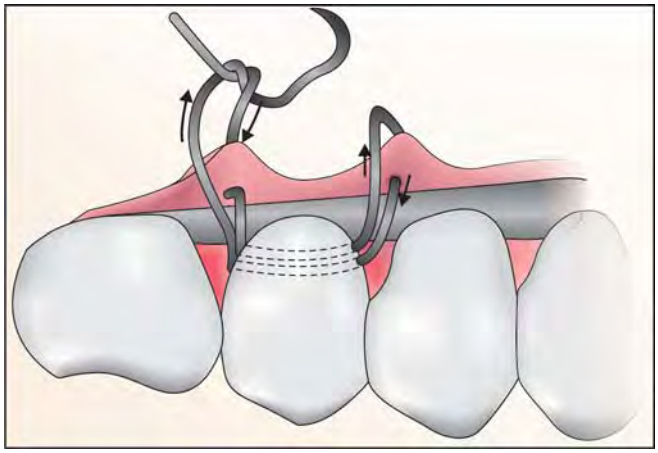


Fig. 18.40: Vertical mattress suture

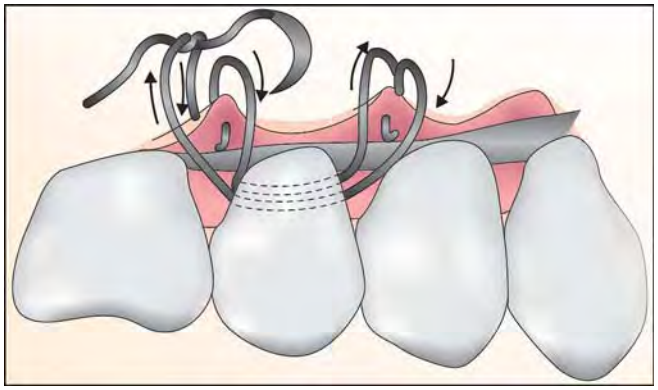


Fig. 18.41: Single sling suture

Single sling suture (Fig. 18.41): Single sling suture is similar to the vertical mattress suture. The needle is passed through the attached gingiva of the flap, through the interdental embrasure, but not through the lingual soft tissue. It is then directed lingual to the tooth and passed through the opposite interdental embrasure and over the incisal or occlusal margin of the flap. The needle is then passed through the attached gingiva of the flap, from the buccal or facial side, to the embrasure, passed lingual to the tooth, through the opposite embrasure, passed over the flap margin, and tied with a knot. This technique is helps in obtaining the maximum incisal or occlusal level during repositioning.

GRAFT MATERIALS USED IN POST-SURGICAL OSSEOUS DEFECTS

Autologous Platelet Rich Plasma (Platelet Gel) was developed in the early 1970s as a by-product of multi-component pheresis. Techniques and equipment have dramatically improved through the 1990s. This is a new procedure which utilizes the patient's own (autologous) platelets.

PRP contains following growth factors:

- PDGF (Platelet Derived Growth Factor)
- EGF (Epidermal Growth Factor)
- IGF (Insulin Growth Factors)

Platelet Growth Factors

- Increase tissue vascularity through increased angiogenesis
- Are chemotactic for monocytes, macrophages, and fibroblasts
- Enhance collagen synthesis
- Increase the rate of epithelial and granulation tissue production
- Enhance osteogenesis
- The high concentration of leukocytes in the buffy coat add an antimicrobial effect, while wound hemostasis and lymphatic sealing provide an opportunity to eliminate postoperative drains and reduce pain
- Provide watertight seal for dural closures
- When mixed with auto/allograft bone fragments, it forms a putty-like form. Ideal for packing of structural reconstructions
- Provide for an immediate surgical hemostatic agent that is biocompatible, effective and safe.

Osteogenic Proteins (Bone morphogenic proteins)

Osteogenic proteins also referred to as Bone morphogenetic, or Bone Morphogenic Proteins (BMPs), are a family of bone-matrix polypeptides isolated from a variety of mammalian species. Implantation of Osteogenic proteins induces a sequence of cellular events that lead to the formation of new bone.

Some of the potential clinical applications of osteogenic proteins are:

- As a bone graft substitute to promote fusion and to aid in the incorporation of metal implants,
- To improve the performance of autograft and allograft bone,
- As a graft agent for osteochondral defects.

Recombinantly produced human osteogenic protein-1 (OP-1), also known as BMP-7, was developed

Fig. 18.42: Cerasorb

by Stryker Biotech. These osteogenic proteins have been successfully used as graft materials in post surgical defects and also in tissue engineering.

Cerasorb (Fig. 18.42)

Cerasorb is a >99 percent pure phase beta-tricalcium phosphate (beta-TCP) certified for the regeneration of bone defects in the entire skeletal system. Furthermore, it was the first synthetic material to be certified in Europe as a carrier for patient's own PRP. Cerasorb offers bone regeneration instead of reparation.

Cerasorb is completely resorbed without any residue and replaced by natural, vital bone at a resorption rate adjusted to the formation of the new bone. Depending on the type of bone (desmal/chondral), this process takes place within a definable time period of generally 3 - 24 months.

Safety and Bio-compatibility

- As a purely synthetic material, Cerasorb is free from any risk of material-induced infection.
- There is no immunologic defence reaction.
- The rounded surface of the Cerasorb granules prohibits mechanical irritation of the surrounding tissue and reduces inflammatory reaction.
- The physiologic pH-value in aqueous solution results in excellent bio-compatibility and. degradation of the material into microparticles which avoids undesirable macrophage activity.
- Cerasorb is integrated into the natural bone without connective tissue encapsulation or tissue degeneration and is a highly osteoconductive material.

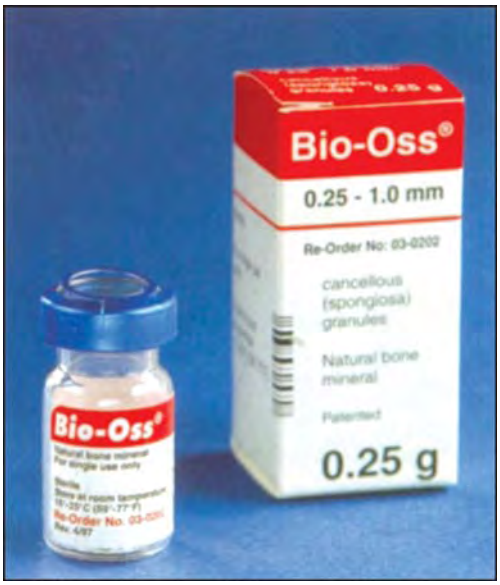


Fig. 18.43: Bio-Oss

OSTEOGRAF/N

OsteoGraf/N is a pure, natural form of hydroxyl apatite with the following characteristics:

- Natural, bovine-derived
- Anorganic
- Microporous
- 100 percent protein free
- Hydrophilic - cohesive consistency when hydrated
- Resorbs at cell-mediated rate

Osteograf/N is the only xenograft that meets all ASTM standards for Composition of Anorganic Bone for Surgical Implants and bone defects.

Bio-Oss Collagen (Fig. 18.43)

Bio-Oss Collagen consists of Bio-Oss Spongiosa granules (0.25-1 mm) with the addition of 10 percent highly purified porcine collagen. As with Bio-Oss, the mineral structure of Bio-Oss Collagen is highly porous, possesses a large internal surface area, and functions as a scaffold for bony ingrowth. The collagen component enables convenient handling and simple application but does not function as a barrier.

Special Properties of Bio-Oss Collagen

- *Simple application:* The collagen fibers hold the spongiosa particles together.
- Simple adaptation: After moistening, the consistency becomes moldable.

- The addition of collagen facilitates adhesion of the particles within the defect.

Other Surgical Techniques

Hemisection/ Root Amputation

Sectioning of the crown of the molar to remove one root with half the crown, which is affected or diseased.

The sectioned crown is usually modified into a premolar shape.

Indications: Usually periodontally affected multirooted teeth.

For example: Heavy bone loss on one root, while other root with minimal bone loss.

Bicuspidization

It is a procedure in which a double- rooted molar is sectioned to create two bicuspids.

It is not a very common procedure. This bisection allows easier cleaning and sometimes, retention of one root when the prognosis is reduced on the other root due to iatrogenic causes.

Indications: Fracture at furcation area

Radisection

It refers to the removal of one or more roots of a molar. The root is sectioned at the level where it joins the crown. It is commonly undertaken in upper molars.

In the author's opinion, it is a complicated procedure with unsure prognosis.

Suture Removal

A perisutural epithelial sleeve develops at 3 days and can cover the entire suture track after 7 days. An intense inflammatory response to suture materials, combined with the trauma of the suture placement is visible after 3 days. The epithelial sleeve itself also causes inflammation during its resorption. Since the epithelial seal at the wound edges is evident within 2 days, suture removal can take place earliest after 48 h but not later than 4-5 days. Time required for wound closure is closely related to the gap between tissue wound margins. Therefore, perfect adaptation will allow earlier suture removal.

More and more variables of wound healing, including patient nutritional status, bacterial infection, wound care and available tissue oxygen, are being researched. Consequently, novel therapies are evolving, such as growth factor therapy. Growth factors may lead to new strategies in improvement of soft tissue healing, including skin, mucosa, and nerve tissue. Management of bacterial growth in the oral environment during the healing phase has been successfully influenced by 0.2 percent chlorhexidine rinse in the first postoperative weeks.

Postoperative Care Following Endodontic Surgery

1. Consume nutritious diet and drink plenty of liquids for the first few days after surgery.
2. Do not lift up your lip or pull back your cheek to see the site of surgery. This may pull the stitches and cause bleeding.
3. There will be little bleeding from where the surgery was done. You may have little swelling and bruising of your face. This should last for a few days.
4. Place an ice-pack on your face where the surgery was done for 20 minutes and take it off for 20 minutes for 6 to 8 hours. After 8 hours, the ice-pack should not be used. The next day after surgery, you can put a soft, wet, hot towel on the site for the next 2 to 3 days.
5. Surgical site will have some soreness. Use analgesics as recommended by the doctor.
6. Use mouth rinses two times a day for 5 days or as prescribed by your doctor.
7. Take the prescribed analgesics and antibiotics regularly for the advised duration.
8. Avoid brushing the teeth near the surgical site. At the same time, proper oral hygiene must be maintained
9. Do not involve in vigorous activity or drink alcohol or use any tobacco for the next 3 days.
10. Report to the dental office promptly for suture removal and contact the office in case of any problems.

Postoperative Sequelae/complications

1. *Swelling and pain:* It may occur to trauma to tissue.
   Prevention—Careful handling of the tissues with minimum damage.
   Proper analgesics should be administered.

2. *Ecchymosis:* It is discoloration of the gingiva-commonly seen in the fair complexion or elderly people. Occurs due to breakdown of blood pigments in the surrounding area and usually disappear in 2-4 weeks.
3. *Anesthesia:* Occurs when surgery is done near the nerve site. If it occurs, it usually disappears in 1-3 months depending upon the damage to nerve Care should be taken while performing surgery in mandibular 1st premolar and molar site. In maxilla, it may occur in 1st, 2nd molar region due to damage to palatal nerves.
4. *Hemorrhage:* It may be due to incomplete removal of granulation tissue or bad handling of tissue (traumatized tissue at surgical site)
   There are various methods to stop hemorrhage:
   - Ice-pack with pressure
   - Bone wax - should be removal after arrest of bleeding.
5. *Perforation:* Common in upper 1st molar when maxillary antrum is in close approximation to the palatal root. Sometimes root end perforations may occur with the use of bur to prepare the root-end cavity. If certain precautions are followed, perforations can be avoided.
6. *Damage to adjacent teeth:* Sometimes damage to adjacent root tips might occur which doing root end preparation. It is an easily avoidable injury and critical evaluation of the radiograph before surgery is a must.
7. *Suturing failure:* Most common complications in retrograde Surgery where improper suturing techniques are undertaken. Proper needle and material selection are hence very essential.

SUGGESTED READING

1. Apaydin ES, Shabahang S, Torabinejad M. Hard-tissue healing after application of fresh or set MTA as root- end-filling material. J Endod 2003;30:21-24.
2. Anusavice KJ. Philips' Science of Dental Materials, 11th edn. St Louis: WB Saunders, 2003. Bahat O, Handelsman M. Periodontal reconstructive flaps - classification and surgical considerations. Int J Periodontics Restorative Dent 1991;11:480-87.
3. Boyne P. Histologic response of bone to sectioning by high-speed rotary instruments. J Dent Res 1966;45:270-76.
4. Brent PD, Morgan LA, Marshall JG, Baumgartner JC. Evaluation of diamond-coated ultrasonic instruments for root-end preparations. J Endod 1999;25:672-75.
5. Carr GB, Bentkover SK. Surgical endodontics. In: Cohen S, Burns RC (Eds): Pathways of the Pulp, 7th edn. St Louis: Mosby, 1998;608-56.
6. Carr GB. Ultrasonic root-end preparation. Dent Clin North Am 1997;41:541-54.
7. Carr G. Microscopes in endodontics. J Calif Dent Assoc 1992;11:55-61.
8. Chong BS, Pitt Ford TR, Hudson MB. A prospective clinical study of mineral trioxide aggregate and IRM when used as root-end filling materials in endodontic surgery. Int Endod J 2003;36:520-26.
9. Cohen S, Burns RC. Pathways of the Pulp, 8th edn. St Louis: CV Mosby, 2002.
10. Dorn SO, Gartner AH. Retrograde filling materials: a retrospective success-failure study of amalgam, EBA, and IRM. J Endod 1990;16:391-93.
11. Economides E, Pantelidou O, Kokkas A, Tziafas D. Short-term periradicular tissue response to mineral trioxide aggregate (MTA) as root-end filling material. Int Endod J 2003;36:44-48.
12. Fisher EJ, Arens DE, Miller CH. Bacterial leakage of mineral trioxide aggregate as compared with zinc-free amalgam, intermediate restorative material, and Super- EBA as a root-end filling material. J Endod 1998;24:176-79.
13. Gerhards F, Wagner W. Sealing ability of five different retrograde filling materials. J Endod 1996;22: 463-66.
14. Gondim E, Zaia AA, Gomes BP, Ferraz CC, Teixeira FB, Souza-Filho FJ. Investigation of the marginal adaptation of root-end filling materials in root-end cavities prepared with ultrasonic tips. Int Endod J 2003;36:491-99.
15. Gutmann JL, Harrison JW. Surgical Endodontics. Boston: Blackwell Scientific Publications, 1991.
16. Gutmann JL, Dumsha TC, Lovdahl PE. Problem Solving in Endodontics, 4th edn. St. Louis: Elsevier- Mosby, 2006.
17. Gutmann JL, Harrison JW. Flap design and incisions. In: Surgical Endodontics. Boston: Blackwell, 1991;162-75.
18. Gutmann JL, Harrison JW. Posterior endodontic surgery:anatomical considerations and clinical techniques. Int Endod J 1985;18:8-34.
19. Gutmann JL, Harrison JW. Closure of the surgical site and postsurgical management. In: Surgical Endodontics. St. Louis: Ishiyaku EuroAmerica, 1994;279-99.
20. Gutmann JL, Pitt Ford TR. Management of the resected root end: a clinical review. Int Endod J 1993;26: 273-83.
21. Harrison JW, Johnson SA. Excisional wound healing following the use of IRM as a root-end filling material. J Endod 1997;23:19-27.
22. Hauman CHJ, Love RM. Biocompatibility of dental materials used in contemporary endodontic therapy: a review. Part 2. Root canal-filling materials. Int Endod J 2003;36:147-60.
23. Jou YT, Pertl C. Is there a best retrograde filling material? Dent Clin North Am 1997;41:555-61.
24. Kerawala CJ, Martin IC, Allan W, Williams ED. The effects of operator technique and bur design on temperature during osseous preparation for osteosynthesis self-tapping screws. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999;88:145-50.
25. Koh ET, McDonald F, Pitt Ford TR, Torabinejad M. Cellular response to mineral trioxide aggregate. J Endod 1998;24:543-47.

26. Kim S, Pecora G, Rubinstein R. Color Atlas of Microsurgery in Endodontics. Philadelphia: WB Saunders, 2001.
27. Kim S. Principles of endodontic microsurgery. Dent Clin North Am 1997;41:481-97.
28. Lee ES. A new mineral trioxide aggregate root-end filling technique. J Endod 2000;26:764-66.
29. Luebke RG. Surgical endodontics. Dent Clin North Am 1974;18:379-91.
30. Mines P, Loushine RJ, West LA, Liewehr FR, Zadinsky.
31. JR. Use of the microscope in endodontics: a report based on a questionnaire. J Endod 1999;25:755-58.
32. Paz E, Satovsky J, Maldauer I. Comparison of the cutting efficiency of two ultrasonic units utilizing two different tips at two different power settings. J Endod 2005;31: 824-26.
33. Peters LB, Wesselink PR. Soft tissue management in endodontic surgery. Dent Clin North Am 1997;41:513-28.
34. Ribeiro DA, Duarte MAH, Matsumoto MA, Marques MEA, Salvadori DMF. Biocompatibility in vitro tests of mineral trioxide aggregate and regular and white portland cements. J Endod 2005;31:605-07.
35. Rainwater A, Jeansonne BG, Sarkar N. Effects of ultrasonic root-end preparation on microcrack formation and leakage. J Endod 2000;26:72-75.
36. Rubinstein RA, Kim S. Long-term follow-up of cases considered healed on year after apical microsurgery. J Endod 1999: 28: 378-83.
37. Siqueira JF Jr. Aetiology of root canal failure: why well treated can fail. Int Endod J 2001;34:1-10.
38. Shabahang S. State of the art and science of endodontics. J Am Dent Assoc 2005;136:44-52.
39. Tagger M, Katz A. A standard for radiopacity of rootend (retrograde) filling materials is urgently needed. Int Endod J 2004;37: 260-64.
40. Velvart P, Peters CI. Soft tissue management in endodontic surgery. J Endod 2005;31: 4. Nair PNR. Pathogenesis of apical periodontitis and the causes of endodontic failures. Crit Rev Oral Biol Med 2004;15:348-81.
41. Velvart P, Peters CI, Peters OA. Soft tissue management: flap design, incision, tissue elevation and tissue retraction. Endod Topics 2006;11.
42. Velvart P, Ebner-Zimmermann U, Ebner JP. Comparison of long term papilla healing following sulcular full thickness flap and papilla base flap in endodontic surgery. Int Endod J 2004;37:687-93.
43. Velvart P, Ebner-Zimmermann U, Ebner JP. Comparison of long term papilla healing following sulcular full thickness flap and papilla base flap in endodontic surgery. Int Endod J 2004;37:687-93.
44. Velvart P, Ebner-Zimmermann U, Ebner JP. Comparison of papilla healing following sulcular full-thickness flap and papilla base flap in endodontic surgery. Int Endod J 2003;36:653-59.
45. Velvart P. Papilla base incision: a new approach to recession-free healing of the interdental papilla after-endodontic surgery. Int Endod J 2002;35:453-60.

19 Traumatic Injuries to the Teeth

INTRODUCTION

Accidental trauma to the dentition is one of the most distressing incidents for an individual during his lifetime. Aside from the pain and discomfort of the injury, the patient's changed appearance makes him/her develop a suppressed sense of personal inferiority. Every dentist must be well prepared to meet these emergencies. It is incumbent upon the dentist to preserve the vitality of injured teeth whenever possible and to restore them skillfully to their original appearance, without producing additional trauma or endangering the integrity of the teeth.

A trauma with an accompanying fracture of an anterior tooth is a tragic experience for the patient and is a problem that requires experience, judgment and skill. The dentist whose counsel and treatment are sought after a trauma is obligated either to treat the patient with all possible means or to immediately refer the patient to a specialist.

Multiple causes contribute to tooth trauma such as automobile accidents, falls and collisions, sporting activities, domestic violence and assaults. Each causative factor presents with unique circumstances combined with the age of the individual. The treatment of the injuries should be commenced as early as possible and the prognosis depends on the rapidity with which the tooth is treated after the injury, regardless of whether the procedure involves protecting a large area of exposed dentin or treating a vital pulp exposure.Treatment of injuries causing pulp exposure and tooth displacement are particularly challenging, and the prognosis of the involved tooth is often uncertain for an indefinite period of time. Advances in dental research have greatly improved the ability of dentists to ensure long-term retention of traumatized teeth in children. It is the dentist's responsibility to stay abreast of this new information and make it available to the patients when they are in need of urgent treatment.

CLASSIFICATION

Dental injuries have been classified according to a variety of factors, such as etiology, anatomy, pathology and therapeutic considerations.

1. *Classification by Ellis and Davey (1960) (Fig. 19.1)*

- This classification is based on numeric system. Though it is simple, is only applicable to the permanent dentition.
- All the primary teeth have been grouped but detailed description has not been given (Grouped as class 9).
- It is one of the most widely accepted methods of classification.

Class I - Simple fracture of the crown involving little (or) no dentin.

Class II - Extensive fracture of the crown involving considerable dentin, but not the dental pulp.

Class III - Extensive fracture of the crown involving considerable dentin and exposing the dental pulp.

Class IV - The traumatized teeth that become non-vital with (or) without loss of crown structure.

Class V - Teeth lost as a result of trauma.

Class VI - Fracture of the root with or without a loss of crown structure.

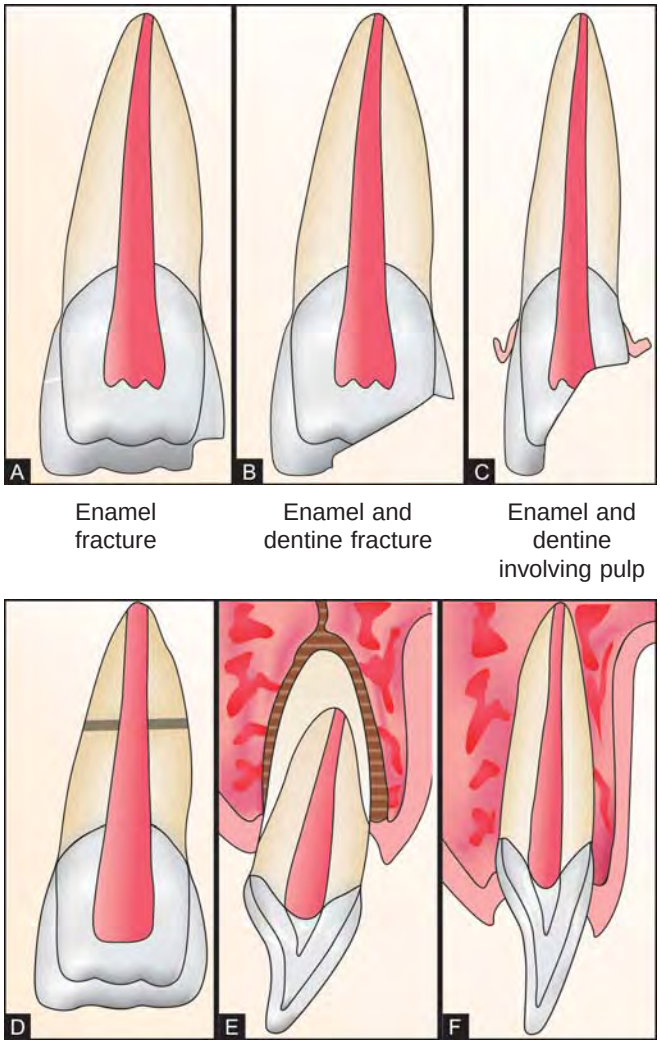


Fig. 19.1: Classification of Dental injuries by ELLIS and DAVEY (1960)

Class VII - Displacement of a tooth without fracture of crown (or) root.
Class VIII - Fracture of crown en masse and its replacement.
Class IX - Injuries to primary dentition

WHO Classification of Traumatic Injuries

The World Health Organization (WHO) described a classification in 1978 with a code number which corresponds to the international classification of diseases:

1. 873. 60 Enamel fracture.
2. 873.61 Crown fracture involving enamel and dentine without pulp exposure.
3. 873.62 Crown fracture with pulp exposure.
4. 873.63 Root fracture.
5. 873.64 Crown root fracture.
6. 873.66 Luxation.
7. 873.67 Intrusion or extrusion.
8. 873.68 Avulsion.
9. 873.69 Other injuries such as soft tissue and laceration.

Andreasen's Modification

873-64 Uncomplicated crown root fracture without pulp exposure

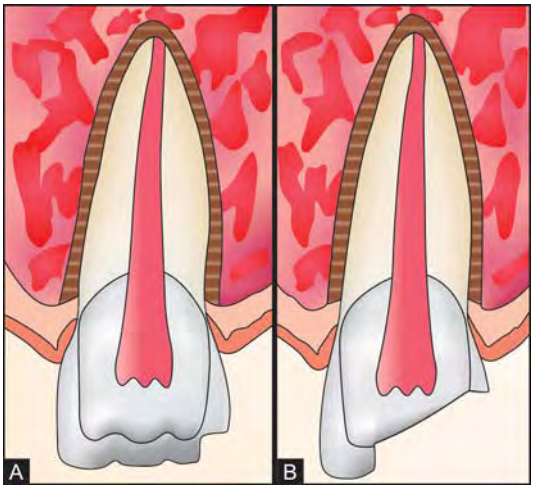
1. 873-64 Complicated crown root fracture with pulp exposure
2. 873-66 Concussion, injury to the supporting structure without displacement with reaction to percussion.
3. 873-66 Subluxation, injury to the supporting structures without displacement but abnormal loosening.
4. 873.66 Lateral luxation displacement other than axial direction with the fracture of alveolar socket.

Recent Classification By WHO (1992) (Fig. 19.2)

The code number is according to the international classification of diseases (1992). The present classification is based on a system adopted by the world health organization in its application of international classification of diseases to dentistry and stomatology. The following classification includes injuries to the teeth, supporting structures, gingiva and oral mucosa and is based on anatomical, therapeutic and prognostic considerations. This can be applied to both the permanent and the primary dentitions.

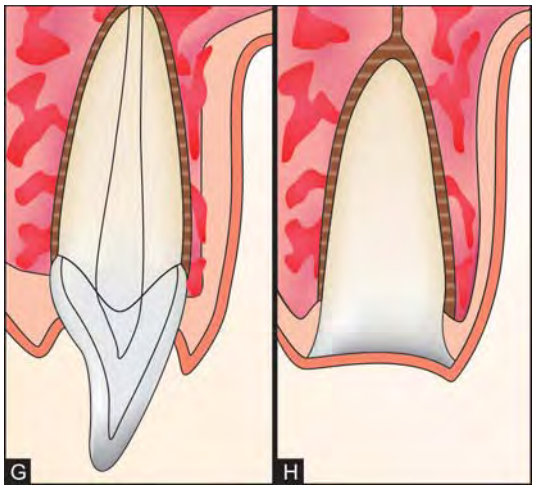
INJURIES TO THE HARD DENTAL TISSUES AND THE PULP

- Enamel Infraction
- (502.50) An incomplete fracture (crack) of enamel without the loss of tooth substance (N502.50).



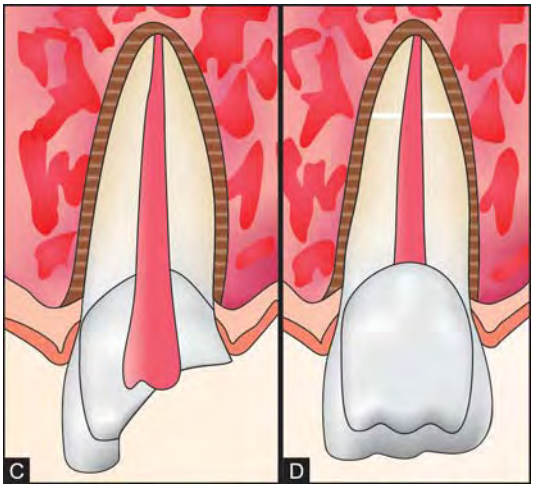
873.60: Enamel fracture

873.61: Enamel and dentin fracture



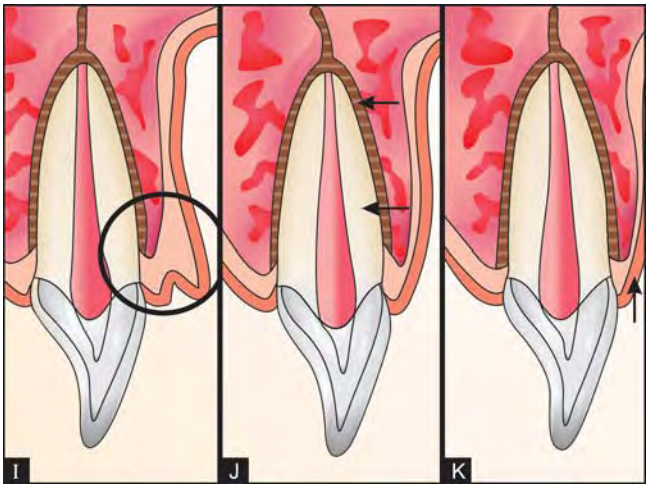
873.67: Extrusion/intrusion

873.68: Avulsion



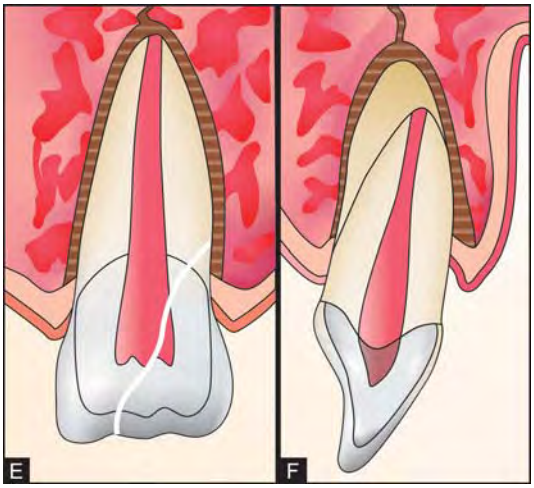
873.62: Crown fracture with pulp exposure

873.63: Root fracture



873-69: Soft tissue injuries

Fig. 19.2: WHO classification



873.64: Crown root fracture

873.66: Luxation

- *Enamel fracture (Uncomplicated crown fracture) (502.50):* A fracture with loss of tooth substance confined to the enamel (N502.50).
- *Enamel-dentin fracture (Uncomplicated crown fracture) (N502.51):* A fracture with loss of tooth substance confined to enamel and dentin, but not involving the pulp.
- *Complicated crown fracture: (N502.52):* A fracture involving enamel and dentin, and exposing the pulp.
- *Uncomplicated crown root fracture (N 502.54):* A Fracture involving enamel, dentin and cementum, but not exposing the pulp.

- *Complicated crown root fracture (N 502.54):* A Fracture involving enamel, dentin and cementum and exposing the pulp.
- *Root fracture (N 502.53):* A Fracture involving dentin, cementum and the pulp.

INJURIES TO THE PERIODONTAL TISSUES

Concussion (N 503.20) (Fig. 19.3): An injury to the tooth supporting structures without abnormal loosening (or) displacement of the tooth, but with marked reaction to percussion.

Subluxation (Loosening) (N 503.20) (Fig. 19.4): An injury to the tooth-supporting structures with abnormal loosening, but without displacement of the tooth.

Extrusive Luxation (Peripheral dislocation, Partial avulsion) - (N 503.20) Partial displacement of the tooth out of its socket.

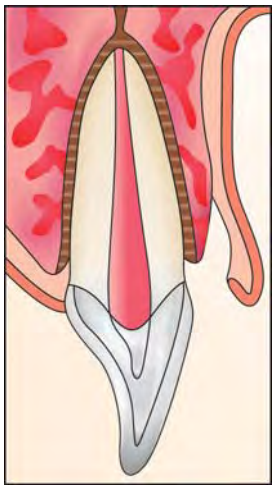


Fig. 19.3: Concussion

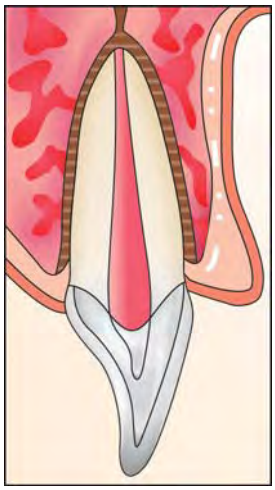


Fig. 19.4: Subluxation

Lateral Luxation (N 503.20): Displacement of the tooth in a direction other than axially. This is accompanied by comminution (or) fracture of the alveolar socket.

Intrusive Luxation (Central dislocation) (Fig. 19.5): (N 503.21) Displacement of the tooth into the alveolar bone. This injury is accompanied by comminution (or) fracture of the alveolar socket.

Avulsion Injuries (N 503.22) (Fig. 19.6): Complete displacement of the tooth out of its socket.

INJURIES TO GINGIVA (OR) ORAL MUCOSA

- *Laceration of gingiva or oral mucosa (S01.50):* A shallow (or) deep wound in the mucosa resulting from a tear and usually produced by a sharp object.
- *Contusion of gingiva or oral mucosa (S00.50):* A bruise usually produced by impact with a blunt object

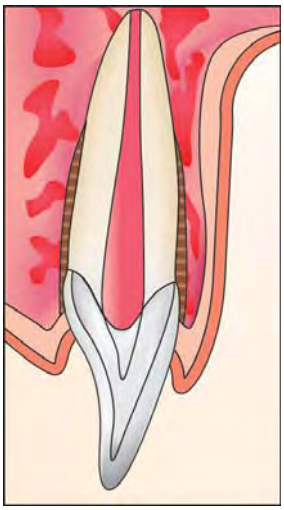


Fig. 19.5: Intrusive luxation

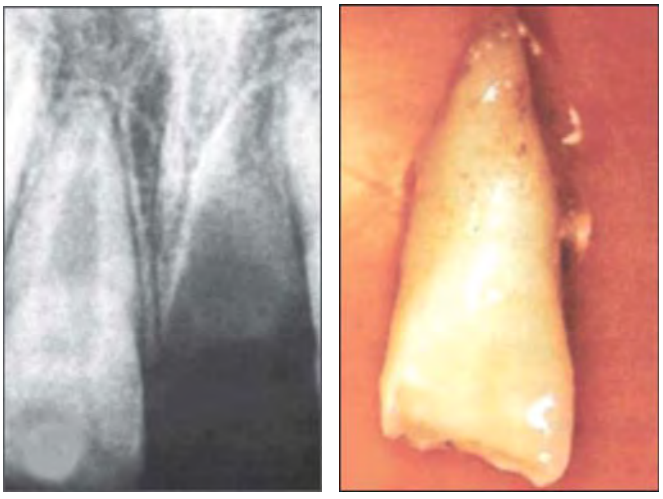


Fig. 19.6: Avulsion

and not accompanied by a break in mucosa, usually causing submucosal hemorrhage.

- *Abrasion of gingiva or oral mucosa (S00.50):* A superficial wound produced by rubbing (or) scraping of the mucosa leaving a raw, bleeding surface.

MODIFICATION OF ELLIS CLASSIFICATION BY MCDONALD (1983)

This classification is a simpler and clearer version of the Ellis classification based on the anatomic and morphological aspect of the anterior tooth.

Class 1 : Simple fracture of the crown involving little or no dentin.
Class 2 : Extensive fracture of the crown involving considerable dentin, but not the dental pulp.
Class 3 : Extensive fracture of the crown with an exposure of the dental pulp.
Class 4 : Loss of the entire crown.

CLASSIFICATION BY HARGREAVES AND CRAIG (1970)

It is a modification of Ellis and Davey's classification but emphasis has been made to the involvement of periodontium along with the coronal and radicular fractures.

Class I - No fracture (or) fracture of enamel only, with (or) without loosening (or) displacement of tooth.
Class II - Fracture of crown involving both enamel and dentin without exposure of pulp with (or) without loosening (or) displacement of tooth.
Class III - Fracture of crown exposing pulp with (or) without loosening (or) displacement of tooth.
Class IV - Fracture of root with or without coronal fracture with/or without loosening or displacement of tooth.
Class V - Total displacement of tooth.

EPIDEMIOLOGY

SEX and AGE Distribution

Boys appear to sustain injuries to the permanent dentition almost twice as often as girls. This is related to their more active participation in games and sports.

- In the permanant dentition, a marked increase in the incidence of traumatic injuries is seen for boys aged (8-10) years, while the incidence is rather stable for girls.
- When injuries affecting primary and permanent teeth are compared,
  a. Trauma to the primary dentition is usually confined to the supporting structures, i.e. luxation and exarticulation.
  b. The largest proportion of injuries affecting the permanent dentition are crown fractures.

SEASONAL VARIATIONS

Several studies have shown that the frequency of dental injuries increases during the winter months.

PREDISPOSING FACTORS

a. Increased overjet with protrusion of upper incisors and insufficient lip closure.
b. Dentinogenesis imperfecta
c. Battered child syndrome.
d. Mental distress and history of previous injuries were shown to increase the risk for dental injuries.
e. Overweight and high alcohol consumption were associated with a high life time prevalence of tooth trauma.

ETIOLOGY

The frequency increases as the child begins to walk and tries to run, due to lack of experience and coordination. The incidence of dental injuries reaches its peak just before school age and consists mainly of injuries due to falls and collisions.

A. *Automobile injuries:*
   i. Multiple dental injuries.
   ii. Injuries to the supporting bone.
   iii. Soft tissue injuries to the lower lip and chin.

B. *Falls and collisions:*
   - When the child reaches school age, accidents in the school playground are very common.
   - They are characterized by a high frequency of crown fractures.

C. *Bicycle injuries:*
   - They result in severe trauma to both the hard and soft tissues due to the high velocity at the time of impact.

- Patients sustaining this type of trauma frequently experience:
  i. Multiple crown fracture.
  ii. Injuries to the upper lip and chin.

D. *Sports:*
- Injuries during the teens are often due to contact sports such as:
  i. Ice hockey.
  ii. Soccer.
  iii. Basket ball.
  iv. American football.
  v. Rugby
  vi. Wrestling.

E. *Assaults:*
- Injuries from fights are prominent in older age groups and are closely related to alcohol abuse.
- This type of trauma usually results in a particular injury pattern characterized by luxation and exarticulation of teeth as well as fractures of roots and/or supporting bone.
- In most of the cases men under the influence of alcohol abuse their wives and children.

F. *Torture:*
- A disgraceful and apparently increasing type of injury is represented by trauma to the oral and facial regions of tortured prisoners.
- The most common type of torture was beating, which resulted in loosening, avulsion or fracture of teeth and soft tissue laceration.
- In some cases, deliberate tooth fractures with forceps were also seen.
- In some cases, electrical torture was described in which electrodes were attached to teeth, lips, tongue and soft tissue over the TMJ, which resulted in very forceful occlusion due to muscle spam.
- This resulted in loosening and fracture of teeth and severe pain in the muscles and TMJ.

G. *Mental Retardation:*
- Incidence of dental injuries among mentally retarded patients is related to:
  i. Lack of motor coordination.
  ii. Crowded conditions in institutions.
  iii. Concomitant epilepsy.

H. *Epilepsy:*
- High frequency of dental injuries in epileptic patients could be directly related to falls during epileptic seizures.

I. *Related Injuries:*
- Many drug addicts suffer from crown fractures of molars and premolars, resulting from violent tooth clenching 3 to 4 hours after drug intake.
- Fractures are confined to buccal and lingual cusps.

MECHANISMS OF DENTAL INJURIES

- The exact mechanisms of dental injuries are mostly unknown and are without any experimental evidence. Injuries can be the result of either direct or indirect trauma.
- Direct trauma occurs when the tooth itself is struck e.g. against playground equipment, a table or chair or any other stationary object.
- Indirect trauma is seen when the lower dental arch is forcefully closed against the upper, as by a blow to the chin in a fight (or) a fall.
- While direct trauma usually results in injuries to the anterior region, indirect trauma usually favors crown-root fractures in the premolar and molar regions, as well as the possibility of jaw fractures in the condylar regions and symphysis.
- The following factors characterize the impact and determine the extent of injury.

1. Energy of Impact

This factor includes both mass and velocity. Examples:

a. A force of high velocity and low mass (Gunshot).
b. High mass and minimal velocity (striking the tooth against the ground).

Various studies have shown that:

i. Low velocity blows cause the greatest damage to the supporting structures and tooth fractures are less pronounced.
ii. In high velocity impacts the resulting crown fractures are usually not associated with damage to the supporting structures.

2. Resilience of the Impacting Object

If a tooth is struck with a resilient or cushioned object, such as an elbow during play or if the lip absorbs and distributes the impact, the chance of crown fracture is reduced while the risk of luxation and alveolar fracture is increased.

3. Shape of the Impacting Object

- Impact with a sharp object favors clean crown fractures with a minimum of displacement of the

tooth, as the energy is spread rapidly over a limited area.
- Impact with a blunt object increases the area of resistance to the force in the crown region and allows the impact to be transmited to the apical region, causing luxation or root fracture.

4. Direction of the Impacting Force

- Frontal impacts to anterior teeth generate forces which tend to displace the coronal portion orally. A different situation arises if the bone and the periodontal ligament resist displacement. Horizontal fracture may occur when the root is firmly locked in its socket.

5. Enamel Prisms

- The orientation of the enamel prisms determines the course of fracture line in enamel. The direction of the fracture in dentin is primarily perpendicular to the dentinal tubules. Experimental evidences have shown that enamel is weakest parallel to the enamel rods and dentin is most easily fractured perpendicularly to the dentinal tubules.

CROWN FRACTURES

The most common causes of crown fractures are falls, automobile accidents and athletic activities.

Classification

Crown fractures are classified according to the following traditional categories.
1. *Infraction:* An incomplete fracture of the tooth without actual loss of tooth substance.
2. *Uncomplicated crown fracture:* A fracture with loss of tooth substance confined to enamel.
3. *Enamel-dentin fracture:* A fracture with loss of tooth substance confined to enamel and dentin, but not involving the pulp.
4. *Complicated crown fracture:* A fracture involving enamel, dentin and pulp.

ENAMEL FRACTURES (FIG. 19.7)

These injuries involve the loss of the portion of coronal tooth enamel subsequent to a force directed perpendicularly or obliquely to the incisal edge of the traumatized tooth.

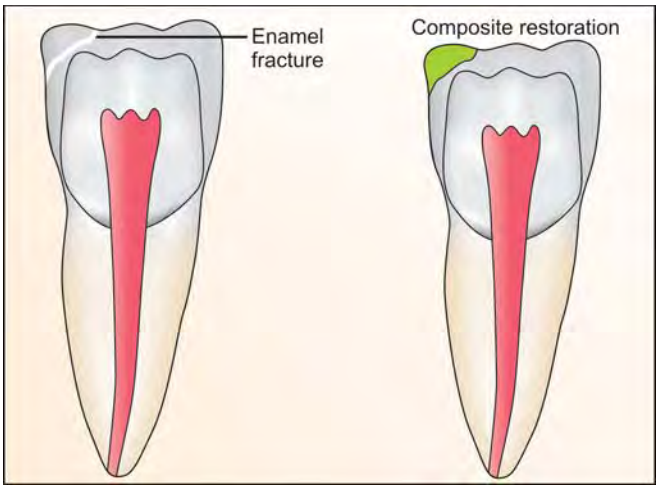


Fig. 19.7: Enamel fractures

BIOLOGIC CONSEQUENCES

If the fracture involves the enamel only the consequences are minimal and any complications may be because of a concomitant injury to the attachment apparatus.

DIAGNOSIS AND CLINICAL PRESENTATION

Enamel fracture includes superficial rough edge that may cause irritation to the tongue or lips. Sensitivity to air or liquids is not a complaint.

Treatment

Enamel fractures: An isolated fracture of the enamel does not usually pose a threat to the health of dental pulp; rather it is an annoyance to the tongue, lips or buccal mucosa.
1. Immediate treatment of crown fractures confined to enamel can be limited to smoothing of sharp enamel edges. This includes recontouring the injured tooth, adjacent teeth and / or the opposing teeth. This treatment is appropriate to eliminate the sharp enamel edges associated with minor injuries and prevents the laceration of tongue, lips or oral mucosa.
2. When the shape and extent of the fracture precludes recontouring a restoration is necessary. This includes restoration of the missing tooth structure with composite resin after acid conditioning of the enamel surface. It is essential

that the crowns anatomy and occlusion be restored immediately in order to prevent labial protrusion of the fractured tooth, drifting or tilting of adjacent teeth into the fracture site or over eruption of opposing incisors.

DENTIN FRACTURES

These injuries involve the loss of tooth substance confined to enamel and dentin but not involving the pulp.

DIAGNOSIS AND CLINICAL PRESENTATION

An enamel and dentin fracture also includes a rough edge on the tooth, but sensitivity to air and hot and cold liquids and pain on mastication may be a chief complaint. The intensity of these symptoms is related directly to the amount of exposed dentin and to the maturity of tooth.

Treatment

The objective in treating a tooth with a fractured crown without pulpal exposure is three fold:

1. Elimination of discomfort.
2. Preservation of vital pulp.
3. Restoration of fractured crown (Figs 19.8 and 19.9)

On initial presentation of a patient for treatment of a crown fracture including enamel and dentin, the tooth should be tested with: a) Electric pulp tester, b) Ice, c) Ethyl chloride spray, d) Periapical radiograph.

Treatment is done in two stages:

1. Temporary restoration: After the fracture, as soon as possible the exposed dentin should be protected by sedative cement such as zinc oxide eugenol held in a crown form. Vitality testing can be conducted with the ethyl chloride spray or ice around the crown margins. The patient is recalled after one month for vitality testing. If the response continues to be within the normal range a permanent restoration may be constructed for the tooth.
2. Permanent restoration (Fig. 19.8): The recommended restoration for uncomplicated crown fractured teeth includes the use of adhesive resin and composite resin systems. The recommended procedure for restoring the fractured segment of an uncomplicated crown fracture includes the following steps:

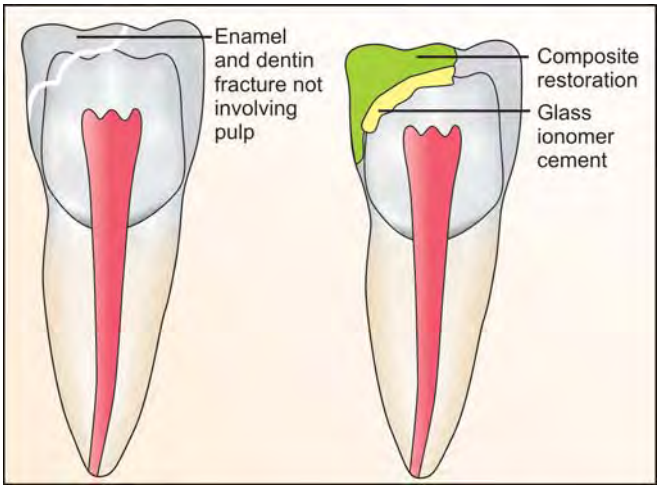


Fig. 19.8: Enamel and dentin fractures

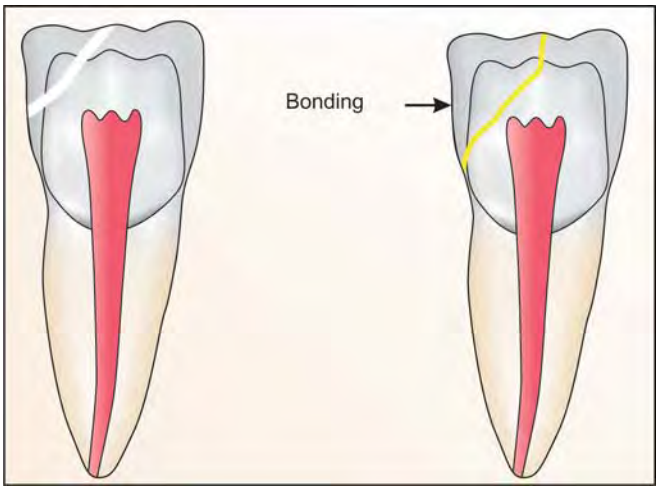


Fig. 19.9: Reattachment

a. Clinical assessment/diagnosis, selection of composite shade for restoration.
b. Cleaning of the fractured tooth, gentle irrigation with an air water syringe.
c. Placing of a glass ionomer liner over the exposed dentin
d. Etching the enamel with 37 percent phosphoric acid, water rinsing and drying.
e. Applying the denting bonding agent.
f. Restoring the tooth to its original contours with composite resin and finishing the margins with a carbide finishing bur and polish as needed.
g. Validating occlusion.

COMPLICATED CROWN FRACTURES (FIG. 19.10)

A complicated crown fracture involves the enamel, dentin and pulp. The exposure of pulp in complicated crown fractures makes the treatment more difficult.

Treatment (Figs 19.11 to 19.13)

Treatment planning is influenced by tooth maturity and extent of fracture. Every effort must be made to preserve pulps in immature teeth.

Choice of treatment depends on the:

1. Stage of development of the tooth.
2. Time between the accident and the treatment.
3. Concomitant periodontal injury.

1. *Stage of development of the tooth:* Root canal treatment on a tooth with a blunderbuss canal is time consuming and difficult. Necrosis of the pulp of an immature tooth leaves the tooth with thin dentinal walls that are susceptible to fracture during and after the apexfication procedure. Therefore, every effort must be made to keep the tooth vital at least until the apex and cervical root have completed their development. In an immature tooth vital pulp therapy should always be attempted, if at all feasible, because of the tremendous advantages of maintaining the vital pulp.
2. *Time between the accident and treatment:* For 24 hours after traumatic injury the initial reaction of the pulp is proliferative with no more than 2 mm depth of pulpal inflammation. After 24 hours, chances of direct bacterial contamination from the pulp

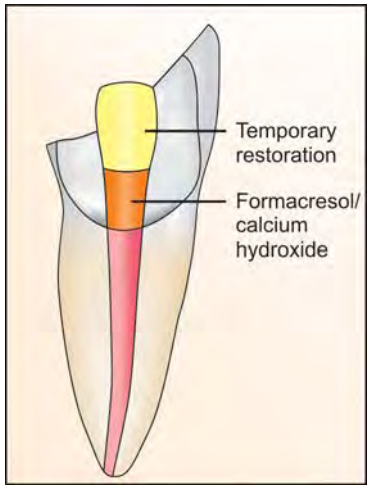


Fig. 19.12: Pulpotomy

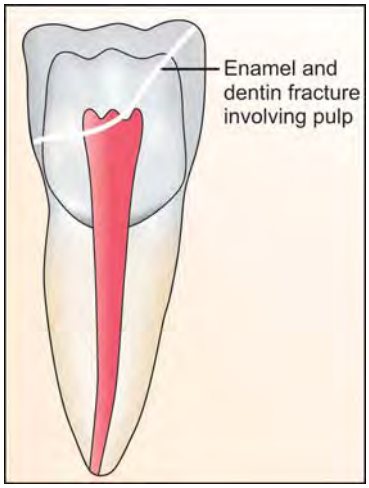


Fig. 19.10: Complicated crown fracture

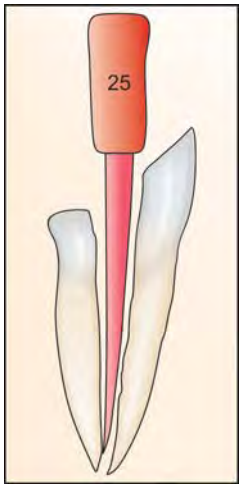


Fig. 19.13: Root canal treatment

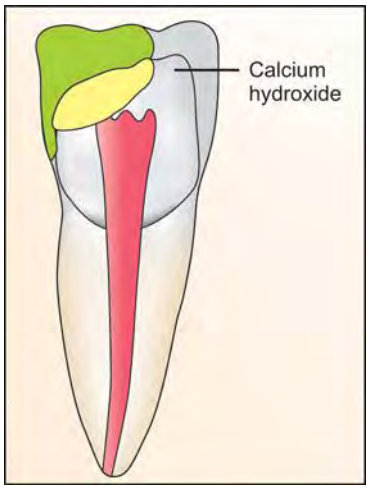


Fig. 19.11: Direct pulp capping with $Ca(OH)_2$

increase with resultant progression of the zone of inflammation in an apical direction. Thus as time progresses, chances of successfully maintaining healthy pulp decreases.

3. *Concomitant attachment damage:* A periodontal injury will compromise the nutritional supply of the pulp. This fact is particularly important in mature tooth where the chance of pulp survival is not as good as for immature teeth.

EXTRUSIVE LUXATION (FIG. 19.14)

Partial displacement of the tooth out of its socket.

Treatment (Fig. 19.15)

Push the tooth back to original position and check occlusion. Use splinting up to three weeks.

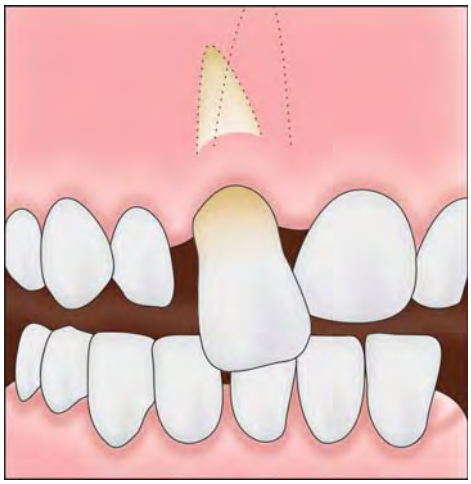


Fig. 19.14: Extrusive luxation

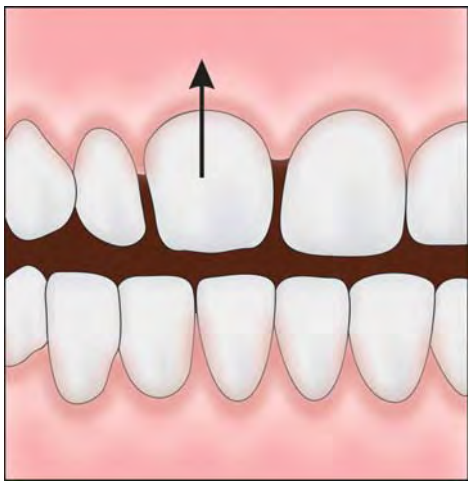


Fig. 19.15: Repositioning

INTRUSIVE LUXATION (CENTRAL DISLOCATION) (FIG. 19.16)

Displacement of the tooth into the alveolar bone. This injury is accompanied by comminution (or) fracture of the alveolar socket.

Treatment (Fig. 19.17)

There are two types of treatment:

1. Orthodontic extrusion.
2. Surgical movement of the tooth to normal occlusion stabilized with splint up to two three weeks (Fig. 19.18)

AVULSION

Definition

It is defined as complete displacement of the tooth from the alveolus.

It is usually the result of trauma to an anterior tooth and is both a dental and an emotional problem.

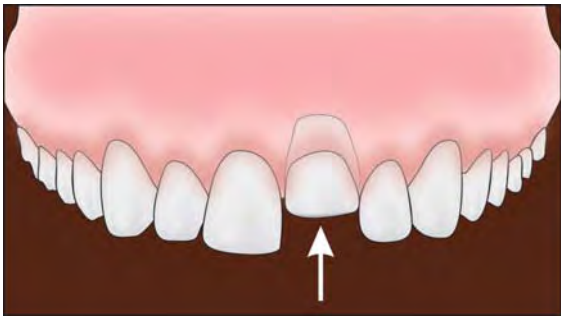


Fig. 19.16: Intrusive luxation

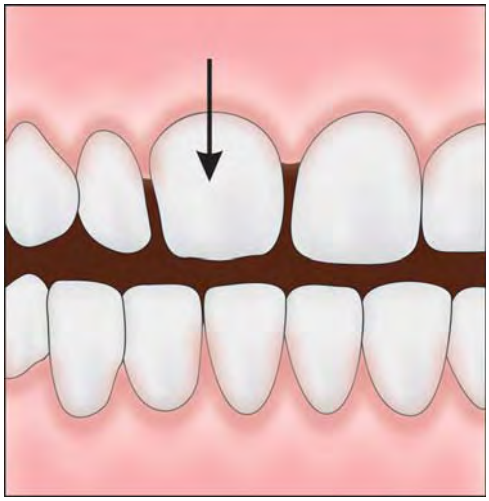


Fig. 19.17: Repositioning

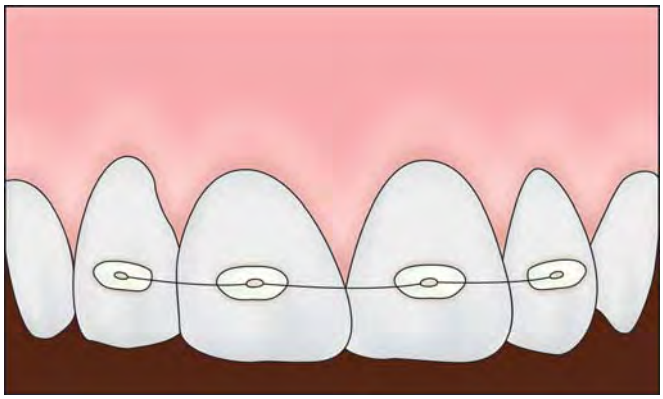


Fig. 19.18: Splinting

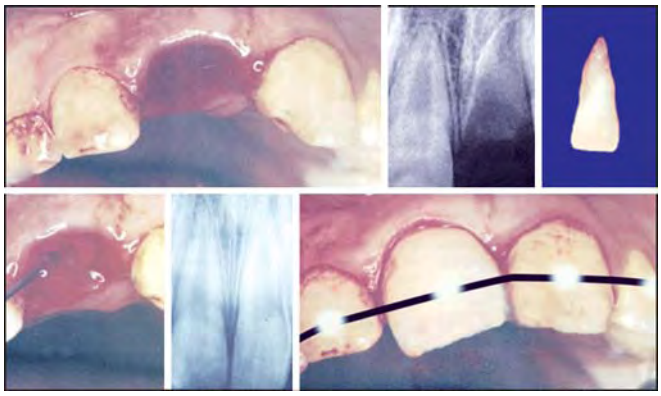


Fig. 19.19: Management of avulsion

Prognosis depends on the amount of time the tooth is out of the socket.

Management (Fig. 19.19)

Success depends on speed with which the tooth is replaced.

Preparation of Root

- If extraoral time is less than 20 mins, periodontal healing is excellent.
- Root is rinsed of debris with water or saline and replanted gently. Prognosis depends on whether root is open or closed.
- If extraoral time is more than 60 mins, periodontal cells would have lost their vitality. In this case the tooth is soaked in citric acid for 5 mins and in 2 percent Stannous fluoride for 5 mins to remove remaining periodontal cells and is then replanted.
- If tooth is dry for more than 60 mins, endodontic treatment is performed extraorally. The socket is lightly aspirated if blood clot is present.

Splinting: To be done for 7-10 days:

- The splint should allow physiologic tooth movement during healing to prevent ankylosis .
- After splinting, traumatic occlusion is avoided.
- After 7-10 days splint is removed, since one week is sufficient to create periodontal support.
- In case of alveolar fracture, splint is placed for 4-8 weeks.
- Management of soft tissues is done.

ROOT FRACTURE

Healing or Repair After Root Fracture

- Healing events following root fracture are initiated at the site of pulpal and periodontal ligament involvement and this creates two types of wound healing response.
- These processes apparently occur independently of each other and close the injury site with either pulpal or periodontally derived tissue.
- On the pulpal side of the fracture, two healing events might occur, depending upon the integrity of the pulp at the level of fracture.

A. If the pulp is intact at the fracture site, it will react in a manner analogous to a coronal pulp exposure under optimal conditions (i.e. with an intact vascular supply and absence of infection).
   - Odontoblast progenitor cells will be recruited and create a hard tissue bridge which will unite the apical and coronal fragments after 2-3 months.
   - This bridge forms the initial callus which will stabilize the fracture.
   - Callus formation is followed by deposition of cementum derived by ingrowth of tissue from the periodontal ligament at the fracture line, first centrally and gradually obliterating the fracture site.

B. In the event that the pulp is severed or severely stretched at the level of the fracture, a revascularization process in the coronal aspect of the pulp is initiated.
   - In the absence of bacteria, this process will result in obliteration of the coronal pulp canal.

- While the revascularization process is underway, periodontally derived cells can dominate root fracture healing, resulting in union of the coronal and apical root fragments by interposition of connective tissue.
- If bacteria gain access–usually to the coronal pulp–an infected pulp necrosis results, with accumulation of inflamed granulation tissue between the two root fragments.
- During the initial stages of wound healing, traumatized pulpal and hard dental tissues can stimulate an inflammatory response and thereby trigger the release of a series of osteoclast-activating factors.
- Thus, root resorption processes beginning either at the periphery of the fracture line adjacent to the periodontal ligament or centrally at the border of the root canal are observed in 60 percent of root fractured incisors.
- Radiographic and histological observations in human subjects have revealed that the final outcome after root fracture can be divided into the events listed below.

A. HEALING WITH CALCIFIED TISSUE

- This type of healing is dependent upon an intact pulp and is seen in cases with little or no dislocation (i.e. concussion or subluxation) of the coronal fragment and in teeth with immature root formation. A uniting callus of hard tissue has been demonstrated histologically in a number of cases. Dentin, osteodentin or cementums have been found in the repair site.
- In most cases, the innermost layer of repair seems to be dentin, while the more peripheral part of the fracture is incompletely repaired with cementum. Most often, cementum will not completely bridge the gap between the fracture surfaces, but is interspersed with connective tissue originating from the periodontal ligament. Occasionally, a slight widening of the root canal close to the fracture site is seen (i.e. internal surface resorption) followed by hard tissue formation. Partial pulp canal obliteration confined to the apical fragment is a frequent finding.
- Clinical examination of teeth within this healing group reveals normal mobility, as compared with non-injured adjacent teeth; moreover, there is normal reaction to percussion and normal or slightly decreased response to pulpal sensitivity testing.

B. INTERPOSITION OF CONNECTIVE TISSUE

This type of healing is apparently related to a moderately injured pulp (i.e. extrusion or lateral luxation of the coronal fragment) where pulpal revascularization or innervation must be completed prior to pulpal participation in fracture healing.

- In the interim, the periodontal ligament cells dominate the healing process which is histologically characterized by the presence of connective tissue between the fragments.
- The fracture surfaces are covered by cementum often deposited after initial resorption, with connective tissue fibres running parallel to the fracture surface or from one fragment to the other.
- The radiographic features in this type of healing consist of peripheral rounding of the fracture edges and a radiolucent line separating the fragments.
- Clinically, the teeth are normally firm or slightly mobile and with a weak pain response to percussion.

C. INTERPOSITION OF BONE AND CONNECTIVE TISSUE

- Histologically teeth in this healing group demonstrate interposition of a bony bridge and connective tissue between the apical and coronal fragments with a normal periodontal ligament surrounding both fragments.
- In some cases, bone can be seen extending into the root canals.
- This mode of healing is apparently a result of trauma prior to complete growth of the alveolar process; thus the coronal fragment continues to erupt, while the apical fragment remains stationary in the jaw.
- Radiographically, a bone bridge is seen separating the fragments, with a periodontal space around both fragments.
- Total pulp canal obliteration of the root canals in both fragments is a common finding.
- Clinically the teeth are firm and react normally to pulp tests.

D. INTERPOSITION OF GRANULATION TISSUE

- Histologic examination of teeth in this group reveals inflamed granulation tissue between the fragments.
- The coronal portion of the pulp is necrotic while the apical fragment usually contains vital pulp tissue.
- The necrotic and infected pulp tissue is responsible for the inflammatory changes along the fracture line.
- In some cases, communication between the fracture line and the gingival crevice is the source of inflammation.
- Radiographically, widening of the fracture line and rarefaction of the alveolar bone corresponding to the fracture line are typical findings.

SUGGESTED READING

1. Crona-Larson G, Bjarnason S, Noren JG. "Effect of luxation injuries on permanent teeth". Endod. Dent. Traumatol 1991;7:199-206.
2. Cavalleri G, Zerman N. "Traumatic crown fractures in permanent incisors with immature roots: a follow-up study". Endod. Dent. Traumatol 1995;11:294-96.
3. Caliskan MK, Turkun M. "Clinical investigation of traumatic injuries of permanent incisors in Izmir, Turkiye". Endod Dent. Traumatol 1995;11:210-13.
4. Cvek M., Andreasen JO, Bonum MK. "Healing of 208 intraalveolar root fractures in patients aged 7-17 years". Dental Traumatology 2001;17:53-62.
5. Duggal MS, Toumba KJ, Russell JL, Paterson SA. "Replantation of avulsed permanent teeth with avital periodontal ligaments". Endod. Dent. Traumatol 1994;10:282-85.
6. Doyle DL, Dumsha TC, Sydiskis RJ. "Effect of soaking in Hank's balanced salt solution (or) milk on PDL cell viability of dry stored human teeth". Endod Dent. Traumatol 1998;14:221-24.
7. DCNA "Traumatic injuries to the teeth". 1993;39.
8. Donaldson M, Kinirons MJ. "Factors affecting the time of onset of resorption in avulsed and replanted incisor teeth in children". Dental Traumatology 2001;17:205-09.
9. Ebeleseder KA, Glockner K, Pertt C, Stadtler P. "Splints made of wire and composite: an investigation of lateral tooth mobility in vivo". Endod. Dent. Traumatol. 1995;11:288-93.
10. Federico M, Garcia-Godoy "PREVALENCE and distribution of traumatic injuries to the permanent teeth of Dominican children from private schools". Community Dent. Oral Epidemiol 1984;12:136-39.
11. Finn. "Clinical pedodontics". 4th edition, 1988.
12. Feiglin B. "Dental pulp response to traumatic injuries a retrospective analysis with case reports". Endod. Dent Traumatol 1996; 12:1-8.
13. Garcia-Godoy F, Sanchez R, Sanchez JR. "TRAUMATIC DENTAL INJURIES in a sample of Dominican school children". Community Dent. Oral Epidemiol. 1981;9: 193-97.
14. Hargreaves and Craig. "The management of traumatized anterior teeth of children". Churchill, Livingstone, 2nd edition, 1981.
15. Howard S. Selden "Repair of incomplete vertical root fractures in endodontically treated teeth in vivo trials". Journal of Endodontics; 22(8).
16. Lee JY, Yanpiset K, Sigurdsson A, Vann Jr WF. "Laser Doppler flowmetry for monitoring traumatized teeth". Dental Traumatology 2001;17:231-35.
17. McDonald "Dentistry of child and adolescent". 5th edition, Mosby, Harwurt Asia, 1987.
18. Mathewson "Fundamentals of pediatrics dentistry". 3rd edition.
19. O.D. Otuyemi "Traumatic anterior dental injuries related to incisor overjet and lip competence in 12 year old Nigerian children". International Journal of Paediatric Dentistry, 1994;4:81-85.
20. Oulis CJ, Berdouses ED "Dental injuries of permanent teeth treated in private practice in Athens". Endod. Dent. Traumatol. 1996;12:60-65.
21. Oulis C, Vadiakas G, Siskos G. "Management of intrusive luxation injuries". Endod Dent. Traumatol 1996;12: 113-19.
22. PC Lekic, DJ Kenney, EJ Barrett. "The influence of storage conditions on the clonogenic capacity of periodontal ligament cells: implications for tooth replantation". International Endodontic Journal 1998;31:137-40.
23. Perheentupa U, Laukkanen P, Veijola J, Joukamaa M, Jarvelin MK, Laitinen J, Oikarinen K. "Increased life time prevalence of dental trauma is associated with previous non-dental injuries, mental distress and high alcohol consumption". Dent. Traumatol 2001;17:10-16.
24. Schatz JP, Joho JP. "A retrospective study of dento-alveolar injuries". Endod. Dent. Traumatol 1994;10:11-14.

CLASSIFICATION OF RESORPTION

Resorption can be classified clinically into:
1. Internal root resorption (Root canal resorption)
2. External root resorption
3. Cervical resorption (Idiopathic resorption)

Classification of resorption by Anderson:
1. External surface resorption
2. External inflammatory resorption
3. External replacement resorption
4. Internal surface resorption
5. Internal tunneling resorption

Internal Root Resorption (Fig. 20.1)

It is a defect which occurs within the pulp chamber and/or anywhere in the root canal system which causes destruction of the dentin.

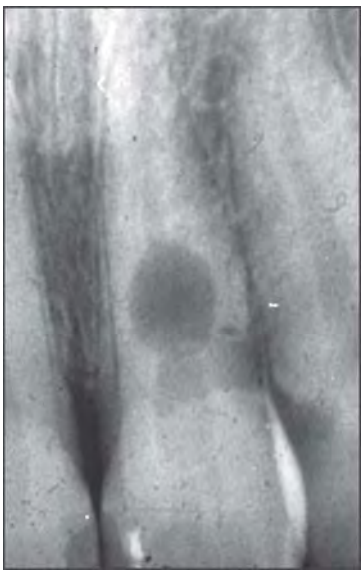


Fig. 20.1: Internal resorption

Etiology: The exact etiology is not known.

Predisposing factors:
- Chronic inflammation of pulp
- Trauma
- Caries
- Any restorative procedure causing severe inflammation of pulp
- Pulp capping
- Pulpotomy

Theories put forward to the mechanism of resorption:
1. The resorption is thought to be due to resorption of the internal aspect of root by multinucleated giant cells present in the granulation tissue within pulp, and these cells are thought to have their origin in infected or necrotic pulp and reach the vital pulp by the route of dentinal tubules.
2. Some authors have explained it as being not of pulpal origin. They say that the resorption occurs due to metaplastic tissue derived from invasion of pulp by macrophage like cells.
3. It has also been proposed that during resorption, some of the areas of pulp are replaced by periodontium like connective tissue which is responsible for the resorption.
4. During restorative treatment, excessive heat may be generated which leads to loss of predentin and the odontoblasts. In such cases, if any infection occurs in the pulp, those areas cannot be repaired leading to resorption.

Types of Internal Resorption

A. Depending upon the duration
   - Transient resorption
   - Progressive resorption

B. Depending on the extent of involvement
   – Non-perforating internal resorption
   – Perforating internal resorption

NON-PERFORATING INTERNAL RESORPTION (INTERNAL SURFACE RESORPTION)

Clinical Features

These are more frequently seen in older age group.

It can occur in any part of the root, but is more common in the cervical third of the tooth

The tooth is usually asymptomatic and painless.

However, characterized by pathognomonic feature of giving an appearance of pink tooth. This is due to the granulation tissue which can be seen through the undermined enamel.

Vitality tests in non-perforating internal resorption usually give positive response. But sometimes, it may give a negative response if the coronal pulp is necrotic.

Radiographic Features

Usually characterized by fairly uniform, well rounded, circumscribed radioluscency seen with smooth borders.

The outline of the canal is distorted.

No radiographic changes seen in periodontium, bone or lamina dura.

It can be differentiated from external resorption or perforating type by using shift cone technique. In non-perforating type, the lesion appears to be centered within the root even after changing the angulation.

Histopathologic Features

Histologically, the area of resorption resembles any granulation tissue with abundant multinucleated giant cells. This conversion of pulp tissue into granulation tissue with resorption caused by giant cells advances from dentinal surface to periphery.

Areas of necrosis are seen in pulp coronal to the granulation tissue. Dentinal tubules may be seen connecting the two areas, filled with microorganisms.

Root canal replacement resorption (Internal tunneling resorption)

Characterized by loss of root substance behind the predentin border which slowly progresses in coronal direction. This is followed by obliteration of the lesion and pulpal lumen.

Clinical Features

The tooth is asymptomatic. Usually found in the coronal fragment of the fractured roots. After some time, the resorption process becomes arrested and complete obliteration of pulp space occurs.

Radiographic Features

It shows irregular enlargement of the pulp chamber. There is progressive loss of root substance with no hard tissue formation in the resorption cavity.

Histological Features

Metaplasia of pulp to cancellous bone is seen. There is continuous build up of bone at the expense of dentin, which is responsible for the resorption.

PERFORATING INTERNAL RESORPTION

This is an internal defect that occurs within the pulp chamber and/or anywhere within the root canal system and causes destruction of dentin and cementum or enamel.

This kind of resorption is characterized by presence of a communication between the pulp and the periodontium. It is usually a severe and aggressive type of resorption.

Clinical Features

The tooth is painful as the tissues are exposed to the external environment.

Vitality tests may give positive or negative results.

Radiographic Features

Here, apart from the radiolucency of the resorptive lesion, we can find some radiographic changes in the periodontium.

There is widening of the periodontal ligament space due to the extension of the granulation tissue into the periodontal tissue from the perforation site.

The lesion appears to shift and is not centered when a shift cone technique is used.

Histological Features

Histologically, it is similar as that of non-perforating internal resorption but extends to the periodontium. However, no resorption of the bone is seen in these

cases and thus can be differentiated from external resorption.

Treatment of Internal Resorption

As presence of pulp tissue is very important for progression of internal resorption, the ideal treatment would be to start the root canal treatment as early as possible.

In case of non-perforating type of resorption, thorough cleaning and shaping of the canal with copious irrigation to aid in cleaning of the inaccessible resorptive areas is recommended during the endodontic treatment. Following this, obturation of the tooth can be done, preferably using warm gutta-percha for better seal.

In case of perforating type, before going ahead with the root canal therapy, the site of perforation needs to be determined.

Also, during endodontic treatment with such perforations, some complications may be encountered like profuse bleeding, which may not stop even on the second visit. This can be controlled by using sodium hypochlorite and placing it in the canal for some time.

Even after this, if the bleeding does not stop, then a mixture of calcium hydroxide and barium sulphate is packed into the canal.

This mixture apart from acting as a hemostatic agent, also helps to find out the site and the extent of the perforation, and healing of the perforation.

The treatment of perforating type of resorption can be done by three ways:

1. When the perforation site is very small and the canal is dry after biomechanical preparation, the tooth can be obturated as done in cases of non-perforating lesions.
2. If hemorrhage control becomes a problem as seen in large perforations, then a mixture of calcium hydroxide and barium sulphate is place for some weeks. Regular follow-up is done to check for the healing of the site. When the perforation heals and the canal is dry to the satisfaction of the dentist, then further completion of endodontic treatment can be done.
3. However, if the bleeding does not stop even after placing calcium hydroxide for several weeks and the perforation site shows no signs of healing, then surgical intervention to close the perforated site is also necessary apart from the endodontic treatment.

External Root Resorption

This kind of root resorption usually occurs following trauma to pulp and periodontal ligament as seen in cases of luxation injuries.

TYPES OF EXTERNAL ROOT RESORPTION

1. Surface root resorption
2. Replacement root resorption
3. Inflammatory root resorption

Surface Root Resorption

Etiology - Luxation injuries

Orthodontic treatment (Fig. 20.2)

After mild trauma to the periodontium, the mechanical damage to cementum occurs, resulting in local inflammatory response and thus localized area of root resorption. If no further trauma is caused and the tooth is allowed to heal, then the lesion is usually is self limiting and gets repaired by about 14 days.

The tooth is asymptomatic.

It is a self-limiting process and heals on its own.

Usually occurs on the lateral surfaces of the root.

Radiographic Features

Usually cannot be seen on bitewing or periapical radiographs.

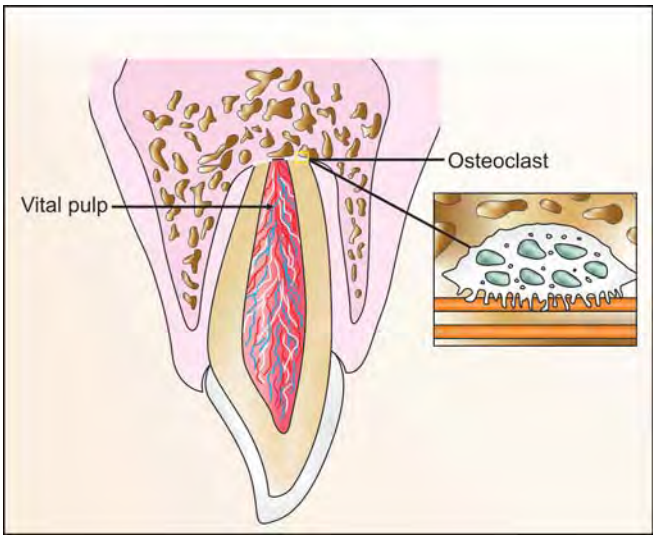


Fig. 20.2: Orthodontic pressure root resorption

Sometimes small excavations of root surface can be seen surrounded by normal lamina dura.

Histological Features

Small resorptive lacunae present on the root. Usually extend only to cementum, but may sometimes extend into the dentin.

Treatment

No treatment is required as the condition is self-limiting and heals on its own.

REPLACEMENT RESORPTION (DENTOALVEOLAR ANKYLOSIS) (FIG. 20.3)

In cases of extensive trauma as in avulsion or intrusive luxation, when a large area of damage involving more than 20 percent of the root surface, then this kind of resorption can occur.

After trauma, there is an initial phase of inflammatory response which is an attempt to clear all the debris. It also clears off the cementum, thus leaving the root vulnerable to being populated by other cells in the vicinity. These areas may become populated by the bone cells leading to deposition of bone in that area, thus leading to dentoalveolar ankylosis.

During remodeling of the bone, the osteoclasts also attack the root surface thus causing continuous resorption of the root which gets replaced by the bone.

Clinical Features

- Metallic sound is heard on percussion
- No mobility of tooth is seen.
- It is not a self-limiting process
- The tooth is asymptomatic.
- The tooth is non-vital and does not respond to vitality tests.
- In due course of time, the tooth is lost due to loss of root support.

Radiographic Features

- Loss of lamina dura. Direct contact between the bone and root.
- Gives rise to moth eaten appearance.

Treatment

No definite treatment can be provided in these cases. If the tooth is non-vital, endodontic treatment can be done. The patient should be explained that the tooth may be lost in due course of time.

INFLAMMATORY RESORPTION (FIG. 20.4)

This is the most severe form of external resorption. After serious injury to the tooth, loss of the cementum and the protective layer of the root occurs. In such condition if the tooth gets infected, then the bacteria from the pulp reach these areas very easily resulting in a severe inflammatory response in the periodontal space, which leads to the resorption of the root.

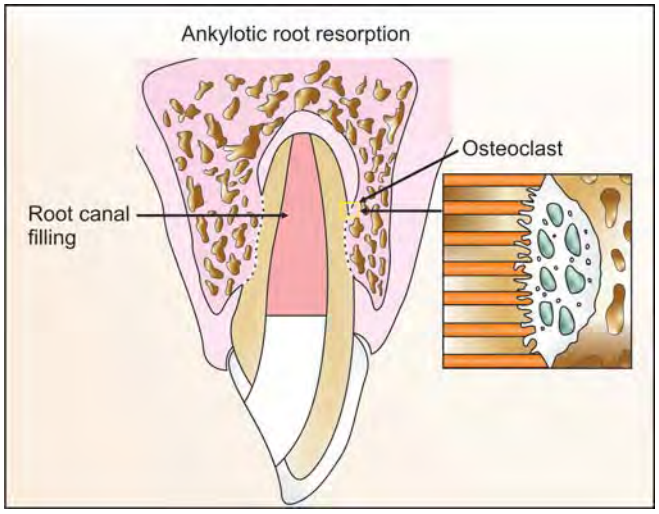


Fig. 20.3: Replacement resorption

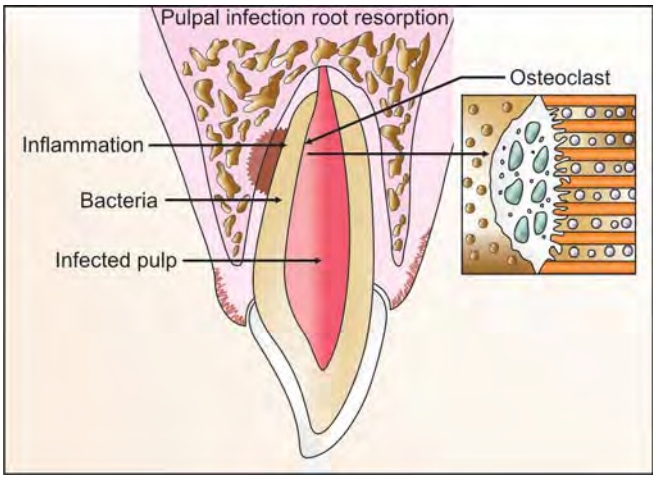


Fig. 20.4: Inflammatory resorption

Clinical Features

The most aggressive kind of resorption. Not a self-limiting process.

Leads to extensive destruction.

The tooth is usually non-vital. The tooth may be symptomatic or asymptomatic.

Radiographic Features

Progressively forming radiolucent areas of both the bone and root are seen.

These areas appear as scooped out radiolucent areas.

Histological Features

Bowl shaped areas of resorption of both the cementum and dentin along with inflammatory response in periodontium seen. The periodontal infiltrate shows granulation tissue with lymphocytes, plasma cells, multinucleated giant cells.

Treatment

Root canal treatment should be done as soon as possible. Sometimes after RCT, a large area of the root is left denuded which can give rise to replacement resorption in that area.

Use of calcium hydroxide has also been suggested as an aid in removal of necrotic tissue due to its bactericidal property.

CERVICAL ROOT RESORPTION (IDIOPATHIC RESORPTION) (FIG. 20.5)

It is a progressive root resorption of inflammatory origin usually found immediately below the epithelial attachment of the tooth. It is called so because it usually occurs in the cervical region.

Predisposing Factors

- Orthodontic treatment
- Non-vital bleaching
- Periodontal treatment
- Orthognathic surgery
- Trauma

It is thought to be caused due to the micro-organisms in the gingival sulcus which cause inflammation in the periodontium resulting in resorption. The pulp in these cases is normal.

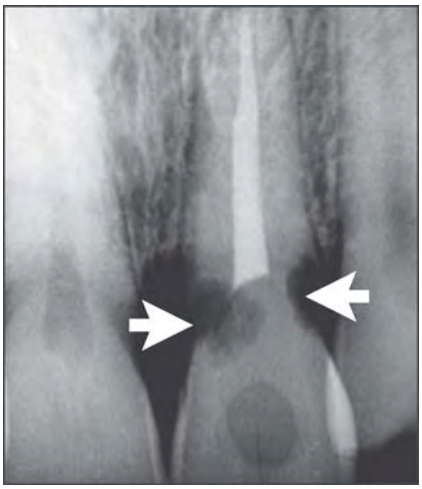


Fig. 20.5: Cervical resorption

It is also thought that, during the treatments mentioned above, some changes may take place in the cementum which changes the ratio of organic and inorganic cementum. It becomes more inorganic, loses its anti-resorptive properties and thus becomes susceptible to resorption.

Clinical Features

The tooth is asymptomatic.

Vitality tests give normal response.

Usually detected only in radiographs.

Sometimes can be associated with sensitivity to thermal stimuli.

Gives rise to pink color which can be confused for internal resorption.

The lesion can spread till the predentin.

There the resorption is controlled and thus starts spreading in lateral direction and starts encircling the tooth.

Commonly misdiagnosed as infrabony pocket. But if probed, a sponge like sensation is obtained and profuse bleeding occurs because of the granulation tissue.

Radiographic Features

Radiolucency seen in the cervical region.

Sometimes may have a mottled appearance if repair has started to occur

Clear outline of root canal visible as pulp is not affected.

Histological Features

Shows histological picture of inflamed tissue with multinucleated giant cells. Sometimes union of bone and dentin may be seen.

Treatment

Surgical correction of the defect needs to be done. No endodontic treatment required as the pulp is not affected in these cases.

SUGGESTED READING

1. Andreasen JO. Traumatic injuries of the teeth, Second edition. Philadelphia, WB Saunders, 1981.
2. Grossman: Endodontic practice, 11th edition.
3. Heithersay GS, Morile AJ. Australian Dental Journal 1982;27:368.
4. Martin Trope: Root resorption due to dental trauma: Endodontic topics 2002;79.
5. Oliet S. Journal of Endodontics, 1984;10:391.

INTRODUCTION

Bleaching as a technique has been performed for over a century. It is one of the most documented clinical techniques in dentistry and yet for reasons unknown, it has escaped the acceptance that it deserves.

Definition

The lightening of the color of the tooth through the application of chemical agents to oxidize the organic pigmentation in the tooth is referred to as bleaching.

The current trend toward cosmetic dentistry has generated more interest in bleaching as patients are asking for whiter and more beautiful teeth. Our society tends to dislike yellowing of teeth that comes with age or the various intrinsic stains that occur developmentally.

Products to "whiten" teeth are plenty in the market. Bleaching alone can significantly change the appearance of teeth, sometimes in only one office visit and almost less invasively and less expensively than procedures such as crowning, bonding or veneering.

HISTORY

Bleaching as yet another means to achieve that dazzling smile is not new; the first reported cases dates back to 19th century.

History of Bleaching Vital Teeth

- VM Torres Zaragoza has reported extensively about bleaching of vital teeth. His report shows that the earliest efforts at bleaching were focused on the search for an effective bleaching agent.
- The first publication of bleaching was in 1877 by Chapple, the agent of his choice was oxalic acid.
- Taft and Atkinson suggested the use of chlorine for bleaching.
- In late 1960s, home bleaching using 10 percent carbamide peroxide was discovered by Klusimer.
- In 1884, Harlan published first reports of peroxide used in bleaching. He called it hydrogen dioxide.
- In 1895, various practitioners began to experiment with electric current to speed the process of bleaching.
- Rossenthal suggested the use of UV waves to help bleaching in 1911.
- By 1918, Abbot had introduced the forerunner of the combination used today - Superoxol and an accelerated reaction by heat and light.
- The technique of nightguard vital bleaching went technically unnoticed until Heywood and Heymann described the technique in March 1989 and a similar product was introdced by a manufacturing company in the same month. The night guard vital bleaching and over the counter kits have kindled a resurgence of interest in tooth bleaching.

History of Bleaching Non-vital Teeth

- As early as 1848, non-vital tooth bleaching with chloride of lime was practiced.
- Truman is credited for introducing well before 1864, the most effective method of bleaching non-vital teeth, which used chlorine from a solution of calcium hydrochlorite and acetic acid. The commercial derivative of this, known as Labarrque's solution, was a liquid chloride of soda.

- In 1895, Garretson published the first report of bleaching non-vital teeth.
- Superoxol (30% H_2O_2) was introduced by a manufacturing company early in the 1900s.
- In 1950, Pearson left the solution of Superoxol for 2-3 days in the pulp chamber.
- Pyrozon (ether-peroxide) was used effectively for non-vital teeth in the late 1950s and early 1960s.
- Nutting and Poe carried out the approach of "Walking bleach" in 1967. They elected to use "Superoxol" instead of "Pyrozone" for safety and combined it with sodium perborate to achieve synergistic effect. They recommended the use of sodium peroxyborate monohydrate because it released more oxygen than sodium perborate. They also advised that gutta percha be sealed before the treatment is initiated. The solution was sealed in the pulp chamber for one week.

CAUSES OF DISCOLORATION

1. Extrinsic discoloration
2. Intrinsic discoloration
3. Internalized discoloration

Stains that occur subsequent to dental development, entering hard tissues through enamel defects.

1. Extrinsic Discoloration (Fig. 21.1)

Definition

Discoloration present on the enamel or aquired pellicle generally of metallic or nonmetallic origin:

- Occurs when some agent literally stains or damages the enamel surfaces of the teeth. They are found on the outer surface of teeth and are usually of local origin which can be removed by oral prophylaxis.
- Cigarettes, cigars and pipes will produce a yellowish brown to black discoloration, usually in the cervical portion of the teeth and primarily on the lingual surfaces.
- Chewing tobacco stains frequently penetrate the enamel producing a deeper stain (Fig. 21.2).
- Coffee and tea cause severe tenacious discolorations, usually brown to black stains.

2. Intrinsic Discoloration

Definition

Discoloration is a result of change in the structural form or the composition of dental hard tissues.

These are stains within the enamel and dentin caused by the deposition or incorporation of substances within these structures, such as tetracycline stains, dentinogenesis imperfecta and fluorosis by products released into the dentinal tubules during illness (e.g. bilirubin involved with jaundice) trauma (primarily the breakdown of hemoglobin), or pigmentation escaped from the medicaments and materials used in restorative dentistry.

1. Tetracycline Staining (Figs 21.3A to D)

Tetracycline staining was first reported in mid-1950s, less than a decade after widespread use of this antibiotic.

- Teeth are most susceptible to tetracycline discoloration during their formation, i.e. during the second trimerster in utero to roughly 8 years after birth.

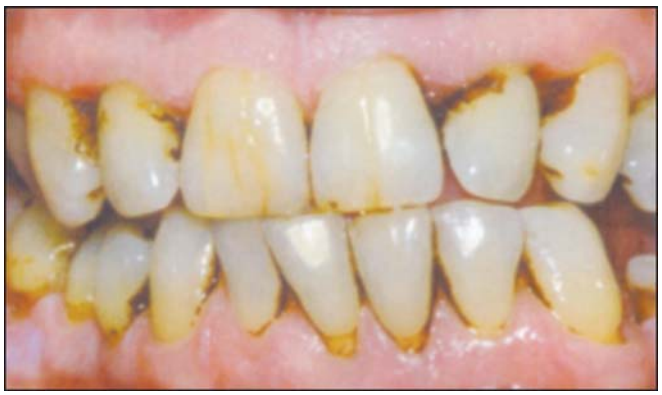


Fig. 21.1: Extrinsic stains

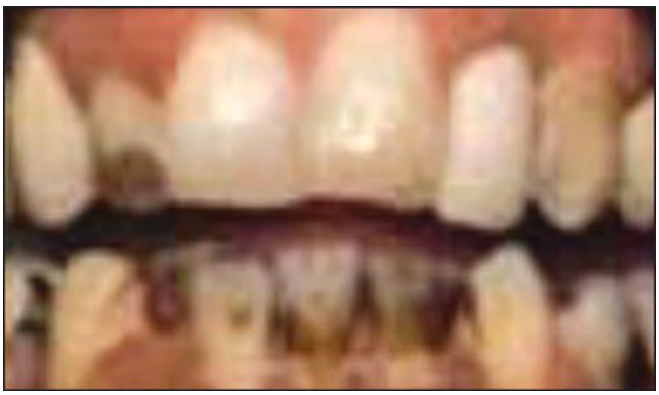
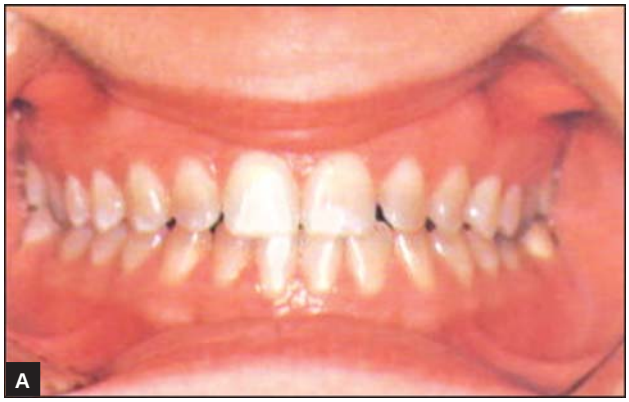
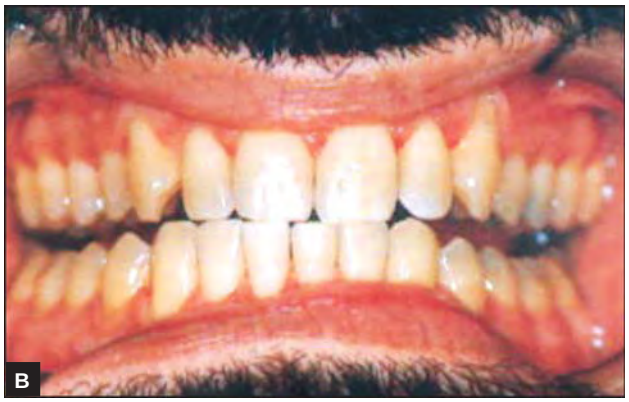
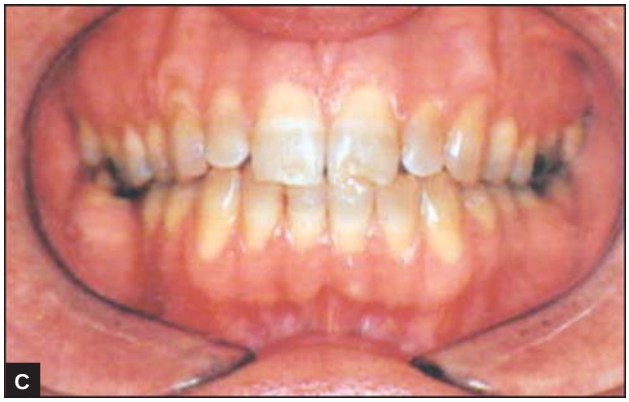
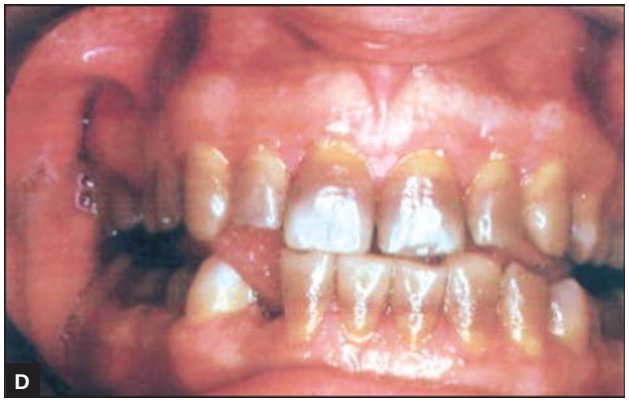


Fig. 21.2: Discoloration due to tobacco









Figs 21.3A to D: Tetracycline stains

- The tetracycline molecules appear to chelate with calcium and become incorporated into the hydroxyapatite crystals.
- The tetracycline involves predominantly the dentin.
- Severity of the stains depends on the time and duration, the dosage of the drug administration, and the type of tetracycline.

Categories of Tetracycline Discoloration

According to Jordan and Boksman:

First degree tetracycline staining:
- Is a light yellow, brown or gray staining.
- Uniformly distributed throughout the crown.
- No evidence of banding or localized concentration. Responds well to bleaching in two or three sessions.

Second degree tetracycline staining:
- Dark or gray staining.
- More extensive than first degree with no banding. Responds well to bleaching in 4 to 6 sessions.

Third degree tetracycline staining:
- Dark gray or blue with marked banding.

Responds to bleaching but bands usually evident following extensive treatment. It may be removed with some veneering technique.

Fourth degree tetracycline staining:
- Includes those stains that are too dark to attempt vital bleaching.

2. Fluorosis Staining

- Mottled enamel that occurs when children ingest excessive fluoride during development of enamel and dentin.
- Damage occurs during development usually from third month of gestation through eighth year of life.
- High concentration of fluoride in excess of 1ppm (more than 4 ppm - moderate to severe discoloration) is believed to cause a metabolic alteration in the ameloblasts resulting in defective matrix and improper calcification.
- Prevalence - premolars, 2nd molars, maxillary incisors, canines, 1st molars and mandibular incisors.
- There are two types of damages:
  1. Discoloration.
  2. Surface defects.

Types

1. Simple fluorosis staining appears as brown pigmentation on a smooth enamel surface (Fig. 21.4).
   - Responds well to bleaching.
2. Opaque fluorosis appears as flat gray or white fleeks on enamel surface (Fig. 21.5).
   - Responds poorly to bleaching because tooth cannot be bought to lightness in the affected area.
3. Fluoride staining with pitting has dark pigmentation with surface defects, necessitates bleaching followed by composite resin bonding (Fig. 21.6).

3. Discoloration from Pulp Necrosis (Fig. 21.7)

a. *Trauma-related discoloration*
   - Trauma can cause hemorrhage as blood vessels rupture in the pulp chamber.
   - Blood is hydraulically driven into the dentinal tubules, where the RBC undergo hemolysis liberating hemoglobin. Hemoglobin is degraded releasing iron that forms a black compound by combining with hydrogen sulfide to become iron sulfide.
   - Immediately after injury, crown remains pink as blood breaks down. The tooth becomes orange, then blue, then brown or black.

b. *Pulp degeneration without hemorrhage*
   - Necrotic tissue contains various protein degradation products which create a grayish brown discoloration of the crown.
   - This responds well to non-vital bleaching technique.

4. Iatrogenic Discoloration

Considered intrinsic because it affects inner structure of the tooth.

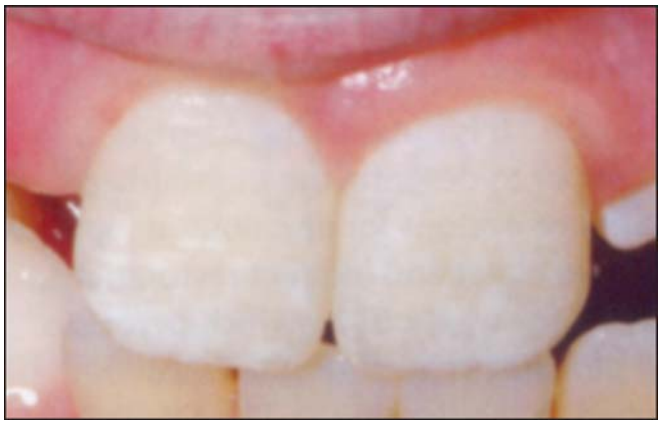


Fig. 21.4: Simple fluorosis

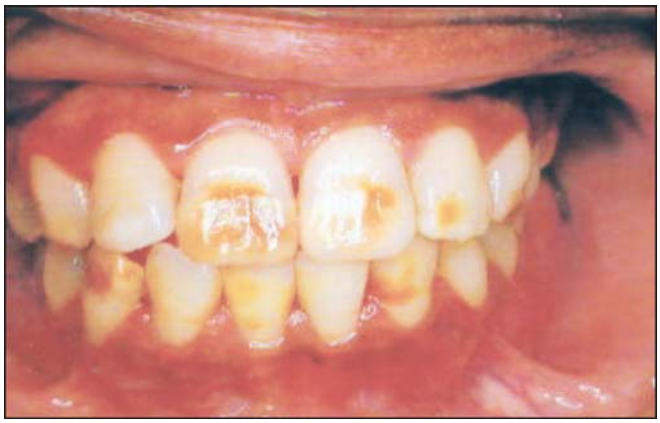


Fig. 21.5: Opaque fluorosis

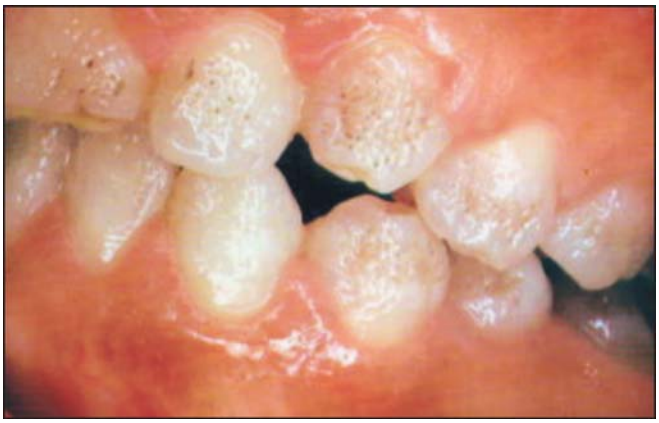


Fig. 21.6: Severe fluorosis with pitting

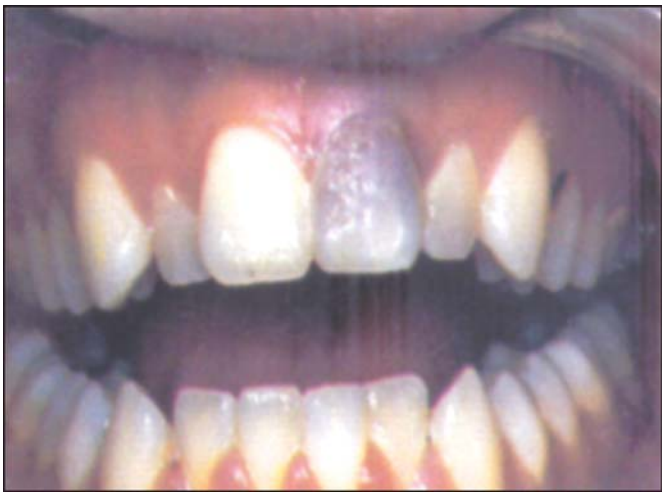


Fig. 21.7: Discoloration from pulp necrosis

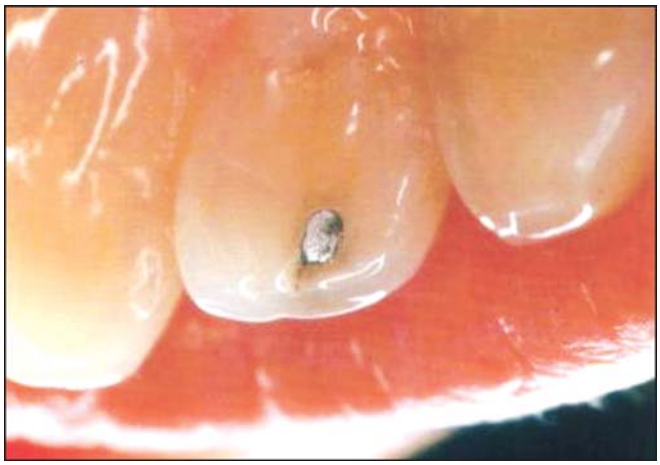


Fig. 21.8: Discoloration due to amalgam

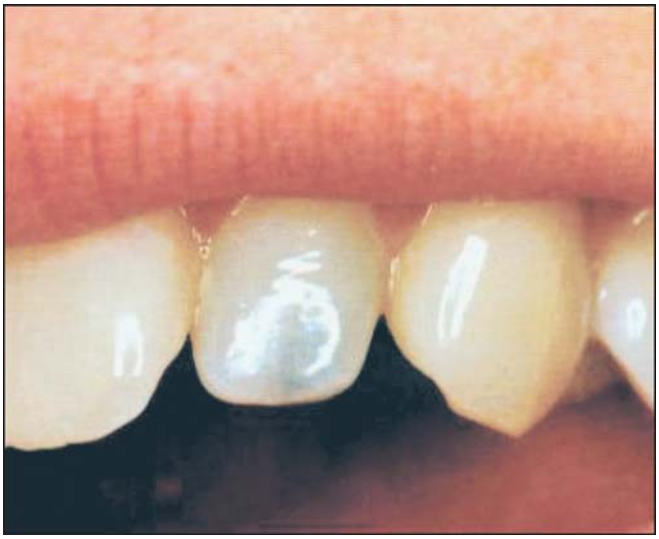


Fig. 21.9: Discoloration due to amalgan

a. Trauma during pulp extirpation "hemorrhage".
b. Failure to remove all pulpal remnants. Responds well to non-vital bleaching technique.
c. Medications and materials used in dental restorations if they leak.
d. Metals like amalgams-reflect as a discoloration through the enamel (Figs 21.8 and 21.9).
e. Breakdown of restorations such as acrylics, silicate cements or composite resins can cause the tooth to look grayer and discolored.
f. Silver nitrates—cause black or bluish black discolorations.
g. Volatile oils—cause yellowish brown stains.
h. Iodine-creates brown, yellow or orange stains.
i. Root canal sealers containing silver cause black stains.
j. Pins cause blue grayish stains.

5. Discoloration as a Symptom of Systemic Condition

- Erythroblastosis fetalis (Rh incompatibility between mother and fetus characterized by breakdown of an excessive number of erythrocytes - degradation of these blood cells causes intrinsic staining of dentin of developing teeth.
- Jaundice results in staining of dentin bluish green or brown by bilirubin or biliverdin.
- Porphyria (rare condition) - excessive pigment production infuses dentin and makes primary and permanent teeth purplish brown.
- Genetic conditions, such as amelogenesis imperfecta, interfering with normal enamel matrix formation.
- Acquired illnesses such as cerebral palsy, serious renal damage and severe allergies, neurologic and other traumatic injuries can interfere with the normal development of the enamel.
- Enamel hypoplasia caused by deficiencies of vitamins A, C, D and calcium and phosphorous during the formative period.

If these conditions cause tooth deformity or white spots, they respond poorly to bleaching.

6. Discoloration due to Heredity and Dental History

- Some people are genetically programmed to have lighter or darker teeth.
- Dental caries may be seen as an opaque halo or as a gray discoloration. Bleaching is not effective until the cause of discoloration is removed.
- Deeper pigmentation as a result of bacterial degradation of food debris in areas of tooth decay or decomposition. If breakdown is repaired, bleaching may not be necessary.

7. Discoloration due to Aging (Fig. 21.10)

1. More stains of coffee and food.
2. Due to wearing away of enamel.

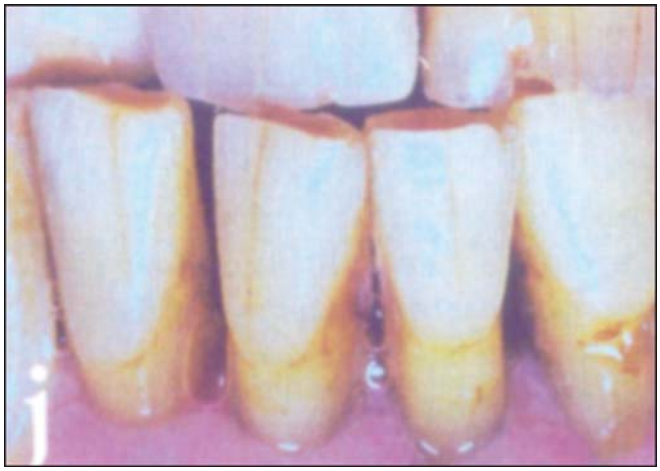


Fig. 21.10: Discoloration due to aging

Advantage in older patients pulp recession makes aging a boon in terms of bleaching, since, it makes the patient less sensitive to bleaching

CONTRAINDICATIONS OF BLEACHING TEETH

Bleaching should not be advised when the pertinent tooth has:

1. Cracks or hypoplastic or severely undermined enamel.
2. Extensive silicate, acrylic or composite restorations.These teeth may not have enough enamel to respond properly to bleaching.
3. Discoloration by metallic salts, particularly silver amalgam. The dentinal tubules can become virtually saturated by these alloys causing stains that no amount of bleaching can significantly improve.
4. Enlargement of the pulp or other disease that makes the tooth sensitive to bleaching solutions or may require special care and desensitization.

MECHANISM OF ACTION

How does Bleaching Work?

The mechanisms of bleaching are not completely understood and may be somewhat different for different types of stains.

- For stains in which pellicle or other organic substances appear on the surface or subsurface of the tooth, the bleaching agent may oxidize these substances.
- The reason why etching sometimes enhances the effects of bleaching may be that, this procedure removes surface organic material and penetrates the enamel slightly, possibly exposing slightly deeper areas of enamel to bleach.
- Substances can penetrate the enamel and dentin, even into the pulp and it is probably this mechanism that allows the bleaching agents to do their work.
- The use of high intensity lighting and longer exposure times for the bleaching agent may work to increase this permeation.
- The mechanism by which bleaching works on the interior of teeth may be a process of oxidation in which the molecules causing the discoloration are released. The theories of photo oxidation or ion exchange are both claimed to be viable reactions.
- For non-vital teeth, the pulp chamber can be packed with a bleaching agent. Although some researchers have presented evidence that hydrogen peroxide can penetrate pulp chamber externally to facilitate oxidation of the staining agents, it is not known whether it would affect the products of hemolysis or degraded substances.
- Hydrogen peroxide, in various concentrations, is the primary material currently used by the profession in the bleaching process. Current In-Office techniques for vital teeth and the "walking bleach" technique typically use 30-35 percent concentration of H_2O_2. Hydrogen peroxide naturally occurs in the body including the eyes, in low concentrations. It is manufactured and regulated by the body and often involved in wound healing. In higher concentrations, it is bacteriostatic and in very high concentrations is mutagenic, possibly by disrupting the DNA strand. However, the body has mechanisms for immediate repair of natural damage and low concentrations of H_2O_2 do not cause serious problems. The carcinogenic capabilities of H_2O_2 are more often caused by other peroxide derivatives and the body uses the peroxidases and other mechanisms for regulating H_2O_2.
- The mechanism of action of H_2O_2 in tooth bleaching is considered to be oxidation, although the process is not well understood. It is felt that the oxidizers remove some unattached organic matter from the tooth without dissolving the

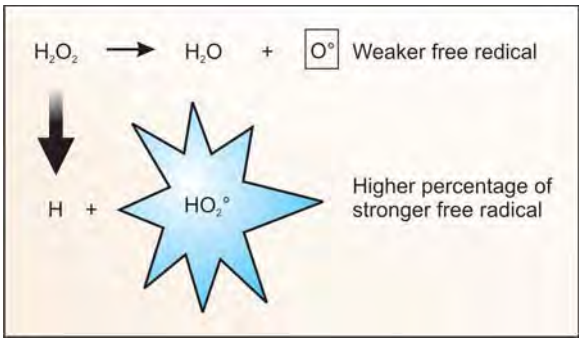


Fig. 21.11A: Release of free radicals from H_2O_2

At Low pH

$H_2O_2 \longrightarrow H_2O + O$ (Weaker free radical.

$\downarrow$

$H+HO_2$ (Lower percentage of stronger free radical)

At High pH (9.5 - 10.8.)

$H_2O_2 \longrightarrow H_2O + O$ (Weaker free radical)

$\downarrow$

$H+HO_2$ (Higher percentage of stronger free radical)

Fig. 21.11B: Mechanism of action of hydrogen peroxide

enamel matrix and may change the discolored portion to a colorless state (Figs 21.11A and B). There is some concern that continued long-term treatment will result in dissolution of the enamel matrix, but reports till date on nightguard vital bleaching techniques have not supported this theory.

- Tetracycline stains are more resistant to oxidation because the molecule is tightly bound to the mineral in the enamel prism matrix during formation and hence is less accessible to immediate action. Teeth stained with tetracycline, therefore, require prolonged treatment times before any results are demonstrated and often are unresponsive to the procedure.
- The majority of products currently on the market for the nightguard vital bleaching technique use a 10 percent carbamide peroxide solution. A 10 percent carbamide peroxide degrades into 3 percent Hydrogen peroxide and 7 percent urea. Hydrogen peroxide can be considered its active ingredient. The urea may provide some beneficial side effects because it tends to raise the hydrogen ion concentration (pH) of the solution.
- In the walking bleach technique for non-vital teeth, sodium perborate is used with hydrogen peroxide. Sodium perborate is a white powder which decomposes into sodium metaborate and hydrogen peroxide releasing oxygen. Hence, when mixed into a paste with H_2O_2, this paste decomposes into sodium metaborate, water and oxygen. When sealed into the pulp chamber, it oxidizes and discolors the stain slowly, continuing its activity over a long period.

Teeth that have been discolored as a result of ingestion of high amount of fluoride such as 5 ppm in natural water do not respond well to ordinary techniques of bleaching. In cases of endemic fluorosis, McInnes solution containing 30 percent H_2O_2, 36 percent HCl acid and 0.2 percent anesthetic ether in the ratio of 5:5:1 is used. The anesthetic ether removes surface debris, hydrochloric acid etches the enamel and H_2O_2 bleaches the enamel. H_2O_2, as described earlier, bleaches the enamel by the process of oxidation. The hydrochloric acid present in the solution increases the penetration of the solution and helps in faster action. But Hydrochloric acid has various deleterious effects such as loss of contour, irritation to gingiva and sensitivity of teeth.

Chen, Xu and Shing (1993) replaced Hydrochloric acid by 20 percent Sodium hydroxide (NaOH) which also helps in decomposition of H_2O_2 and enhances the bleaching effect. NaOH is highly alkaline in nature and therefore dissolves calcium at a slower rate. The results suggests that 1:1 mixture of H_2O_2 with 20 percent sodium hydroxide is as effective as old Mc Innes solution and the calcium dissolved is much less with the new McInnes solution.

A study by Dr Nangrani showed that use of Old McInnes solution resulted in loss of contour of the teeth. The time taken by New McInnes solution was double than that of Old McInnes solution but it did not show loss of contour of the teeth.

Dr Shadwala studied the amount of calcium dissolution with Opalescence night guard vital bleaching solution and Old McInnes solution and found out that Old McInnes solution caused less calcium dissolution as compared to Nightguard vital

bleaching technique. The possible reason for this could be attributed to the fact that night guard vital bleaching technique uses bleaching action which lasts for 6 hours to 2 weeks whereas McInnes solution has to be used for only about 20 minutes (3-4, 5 min applications).

HISTOLOGIC EFFECTS OF BLEACHING

- Since 1951, it has been shown that the bleaching procedures have potentially damaging effects on the pulp and that substances can pass through enamel and dentin and into the pulp.
- 1977, Griffin and Grower reported that Old McInnes solution kept for 2-15 minutes on the teeth showed lack of penetration into the pulp chambers. This lack of penetration may be due to the short exposure time tested.
- In 1950, Wainwright and Lemoine showed that the low molecular weight of H_2O_2 and its capability to denature proteins increases the movement of ions through teeth.

This study was further corroborated in 1999 by C. Hegedus et al who stated that peroxides affect not only the surface but also the inner structure of enamel as a result of their molecular weight. They affect the organic phase of enamel. This inner oxidative effects are more likely to occur in the subsurface enamel which has more organic material.

Cohen and Chase (1979) reported effects of H_2O_2 and heat for vital bleaching. Their conclusion was that using this technique for vital bleaching may be considered harmless to pulpal tissues. The next year in a similar study, Robertson and Melfi found mild superficial inflammation in a signifiacnt number of pulps.

TREATMENT PLANNING

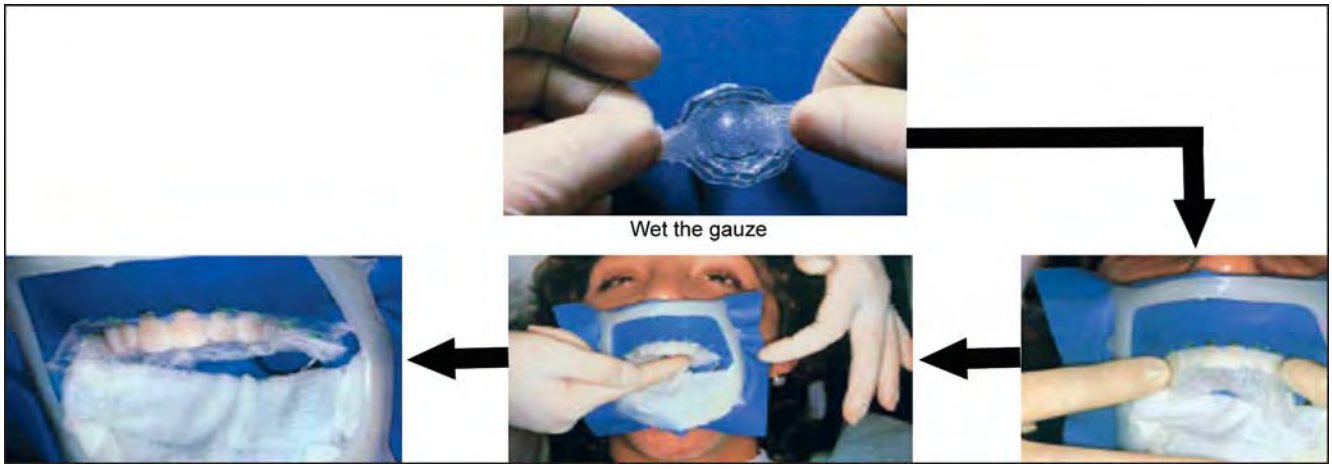
Esthetic dentistry is concerned with the appearance of the mouth as a whole and not simply one or more affected teeth. Bleaching may correct the problem or facilitate other restorative techniques to correct the problem. Bleaching is therefore the first step in any treatment plan. The exact shade of the bleached teeth cannot be predicted. By bleaching first, the advantage is that unnecessary tooth reduction need not be done and anatomic shape and form is preserved. Bleaching may need to be repeated every 1-3 years to maintain brightness of teeth.

Preparation for Bleaching (Fig. 21.12A)

1. Record keeping and photographs—Record keeping should begin at the treatment planning stage. Records should document decision for treatment and alternative. It is absolutely essential to take adequate photographs of patients in preoperative condition. No amount of description can exactly depict how the patient looked before treatment. In addition, photographs are more reliable than memory in documenting the progress of treatment.
2. Careful diagnosis using radiographs and trans-illuminating techniques: In this, the possibilities of any periapical abnormalities can be ruled out. Caries and decalcified or hypocalcified areas will be disclosed. The size and vitality of the pulp can be determined and the opacity, depth and layers of stains can be defined. Also, hypersensitivity of the teeth should be ruled out.
3. Oral prophylaxis and polishing with sodium bicarbonate: this is done to rid teeth of all surface stains, plaque and calculus. The patient should be protected with heavy plastic wrap and safety glasses. In most of the cases, anesthetic may not be used. All members of the dental team should wear protective eye wear, surgical rubber gloves and masks.
4. Preparation of teeth to be bleached. Isolation with:
   a. Rubber dam.
   b. Protective paste-Orabase or Vaseline applied to soft tissues. Recently liquid dam such as opal dam is used.
   c. Gauze saturated with cold water placed under rubber dam.
   d. Pumice used to remove excess stain or protective paste.
   e. Floss is ligated interdentally to prevent seepage of the bleaching solution into the gums.

Instruments

- Early approach used metal instruments and delivered direct heat to the teeth. Patterson developed one such instrument which is advantageous while bleaching individual teeth, as in case of non-vital bleaching.
- A later development was the use of intense light to activate the bleaching solution. Intense light has the advantage of supplying uniform heat to at least ten teeth.



Apply saturated gauze to labial surface

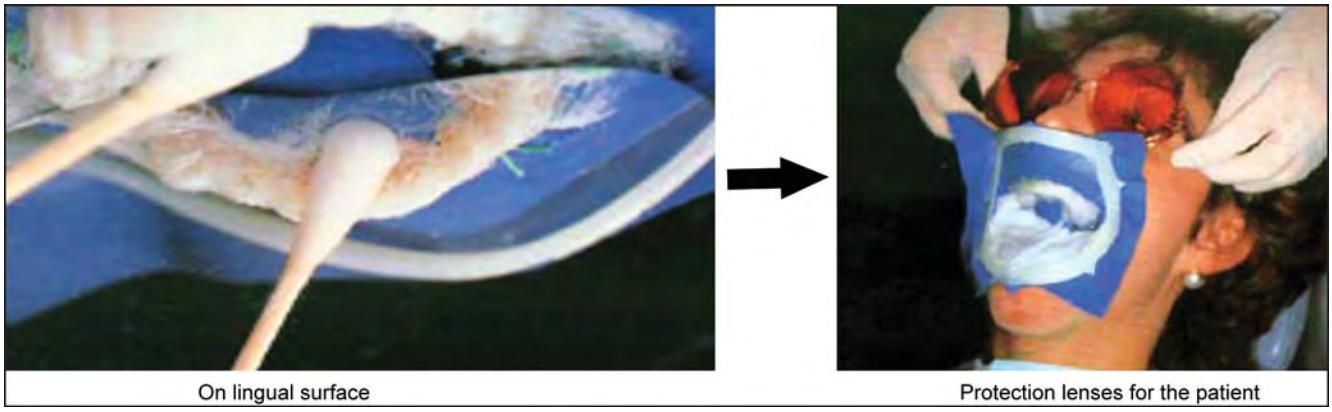


Fig. 21.12A: Patient Preparation

Keep the light about 30 cm (13 inches) from the teeth and direct the beam to surface to be bleached temperature ranges from 115°-140°F (Fig. 2)

Fig. 21.12B: Clinical steps in vital bleaching—Thermocatalytic method

BLEACHING OF VITAL TEETH

There are at least three ways of bleaching vital teeth.

1. In office bleaching or power bleaching techniques:
   - Thermocatalytic method - Light
   - Heat
   - McInnes solution - Old
   - New
2. Night guard vital bleaching.
3. Over the counter preparation.

1. *In office bleaching/Power bleaching (Fig. 21.12B)*
   - First vital bleaching technique (Figs 21.13 to 21.15).
   - ADA accepted products:
     - Superoxol (Sultan Chemists)
     - Starbrite in office bleaching.

Fig. 21.13: Materials used for bleaching

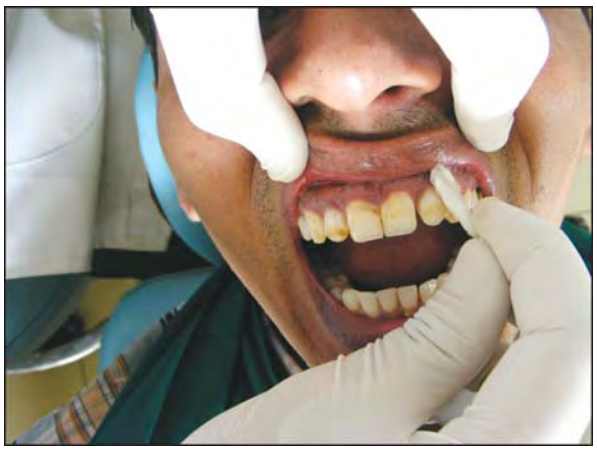


Fig. 21.14: Application of vaseline

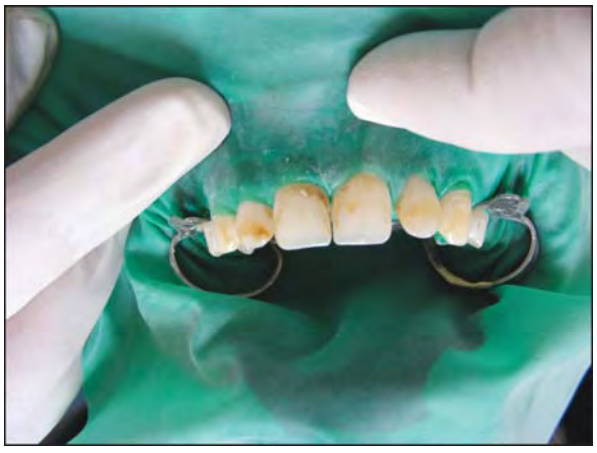


Fig. 21.15: Application of rubber dam

A. *For tetracycline stains*
- Teeth are covered with gauze saturated with 35 percent H_2O_2.
- The peroxide solution may be activated by heat or light.
- Bleaching light positioned 13 inches from the teeth with the light shining directly on them. A rheostat setting of 5 is usually used.
- Where heat is used, a temperature setting of 46-60°C for vital teeth is used.
- The gauze should be kept wet by dispensing fresh bleaching solution with a cotton swab.
- The bleaching agent should be kept in contact and light/heat applied to the teeth for 30 minutes.
- Excess solution rinsed off with copious amounts of warm water. Brush and then polish.
  - At one time, it was advocated to etch the teeth with phosphoric acid before bleaching, to enhance the effect. However, etching is not actually necessary.
  - Tetracycline stains generally require 5-10 visits. Best scheduled every 2-4 weeks.

B. *For fluorosis stains (Figs 21.16 and 21.17)*
- Because fluorosis stains causes much more heterogenous pattern of staining, the bleaching method is more selective.
- Bleaching agent - Old/New McInnes solution.

	(Acidic medium)		*(Alkaline medium)*	
	Old McInnes	*Ratio*	*New McInnes*	*Ratio*
Bleaching enamel	a. 30% H_2O_2	5 parts	30% H_2O_2	1 part
Etches enamel	b. 36% HCl	5 parts	20% NaOH	1 part
Removes surface debris	c. 0.2% ether	1 part	0.2% ether	1 part

- After pretreatment procedures are carried out, cotton applicators carrying fresh bleaching agent are applied for 5 minutes and repeated after an interval of 1 minute.
- Application is repeated till the desired bleaching effect is observed.

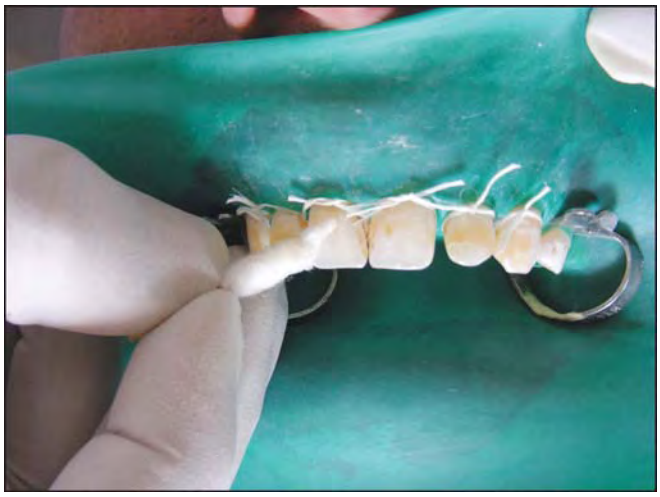
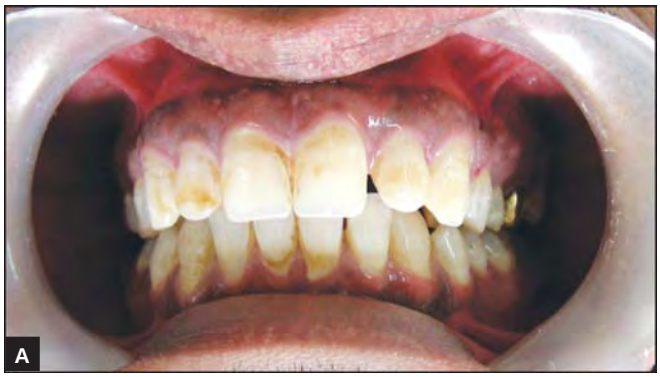
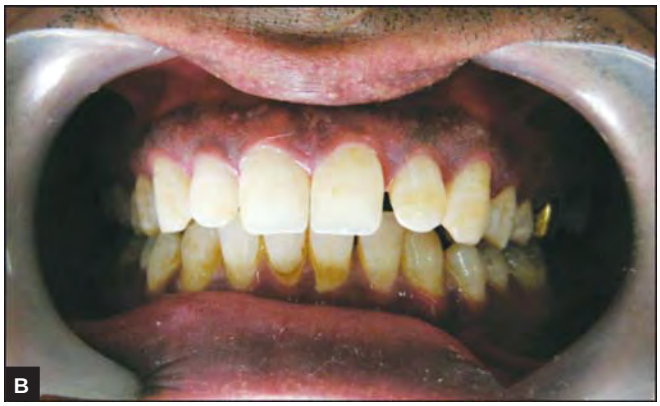


Fig. 21.16: Application McInnes solution



Preoperative photograph



Postoperative photograph

Figs 21.17A to B: Bleaching result

- With Old McInnes solution the solution was neutralized with baking soda.
- Warm water is flushed on the enamel before rubber dam is removed.
- Polishing is done to achieve a high enamel luster.
- *Disadvantages:*
  1. Repeated isolation is a problem.
  2. Power bleach can only be applied on anterior teeth.
  3. 30 percent Hydrogen peroxide is caustic and operator should avoid burning himself/herself or the patient.
  4. Discomfort during procedure and sensitivity for a week after treatment.
  5. No reliable way of predicting success.

2. *Night guard vital bleaching (NGVB/ Dentist prescribed home applied technique/ Dentist home bleaching/ Matrix bleaching) (Figs 21.18 to 21.22).*
   - Introduced by Haywood and Heymann in 1989.
   - Custom fitted prosthesis filled with 10 percent carbamide peroxide is worn for few hours each day for a few weeks.
   - Carbamide peroxide consists of approximately 3 percent Hydrogen peroxide and 7 percent urea. Hydrogen peroxide degrades into water and oxygen while urea degrades into ammonia and carbon dioxide. All these materials occur naturally in the body and are easily managed. Usually 10 percent carbamide peroxide solution is used.
   - Lesser concentration of carbamide peroxide (5% instead of 10 and 16%) can also be used. It takes longer time but may lead to less sensitivity as compared to the higher concentration solutions.

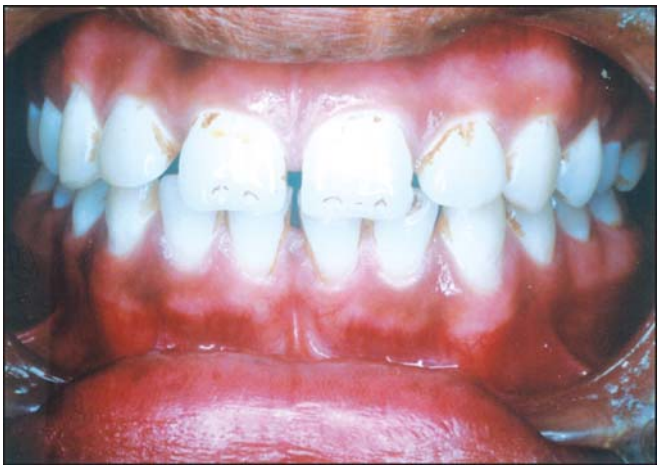


Fig. 21.18: Preoperative photograph

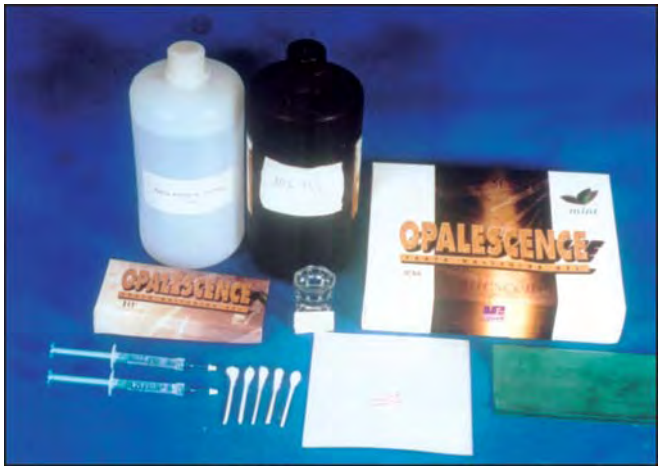


Fig. 21.19: Materials used

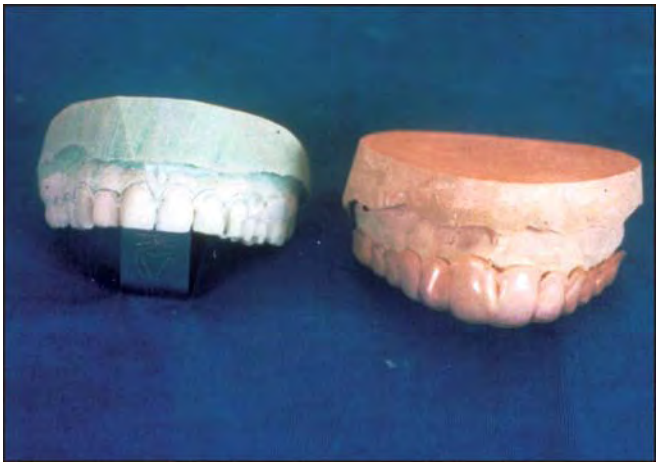


Fig. 21.20: Adaptation of softray on maxillary cast

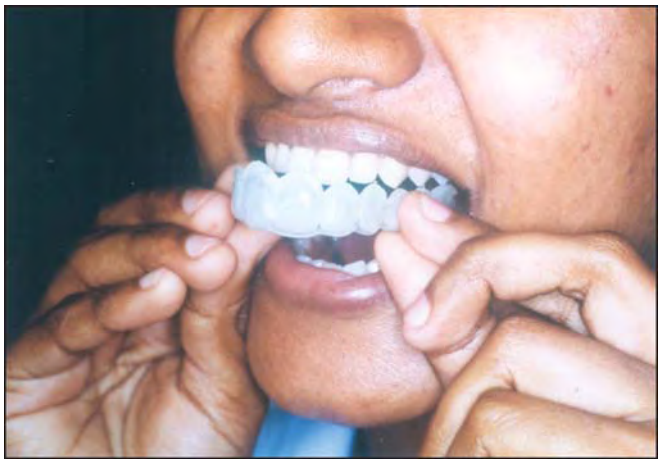


Fig. 21.21: Try-in of the custom-made tray

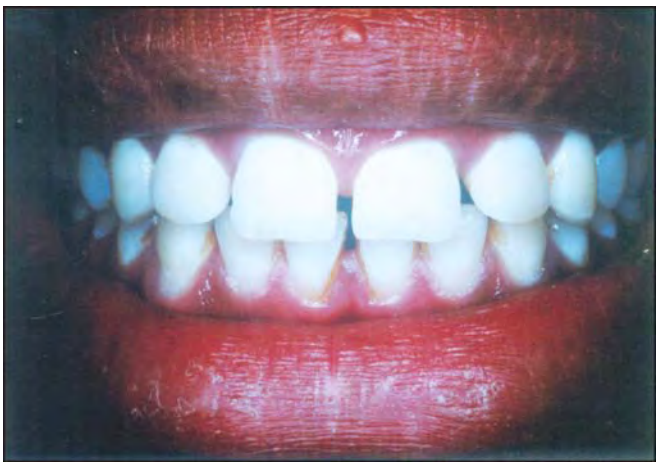


Fig. 21.22: Postoperative photograph

- Carbopol (BF Goodrich) is added to this solution to make it stickier, and prolong the oxygen release. This type of material favours overnight wear.
- Patients who find it uncomfortable to wear it overnight, are advised to place it 2-4 hours before sleeping. Disadvantage is that the treatment time is prolonged.

ADA accepted bleaching products for NGVB

- Colgate Platinum Overnight Professional Tooth Whitening system.
- Nite White classic.
- Opalescence whitening gel.
- Patterson Brand tooth whitening gel.
- Rembrandt Lighter bleaching gel.

3. *Over the counter bleaching systems (e.g: Perfect Smile System)*
   - Shortly after the nightguard systems were introduced, several systems were sold directly to the consumers.
   - Also called "home bleaching" systems but are more appropriately referred as OTC home bleaching systems.
   - Some of the earlier systems have a 3-step procedure.
     - An acidic pre-rinse.
     - Application of a lower strength peroxide material without a prosthesis.
     - A final application.
   - Later developed were home systems which use same strength of bleaching solution as the dentist home system but apply the material with a "boil and form" mouth guard.

Enamel Microabrasion Technique

One of the relatively new techniques for removal of stains in endemic fluorosis cases is the use of enamel microabrasion technique.

In 1916, Dr. Walter Kane, of Colorado Springs, used 18 percent hydrochloric acid with a warm instrument to successfully remove stains associated with endemic fluorosis. Since 1916, numerous investigators have used hydrochloric acid alone on fluorosis stains. In 1984, Mc Closkey described Kane's work and demonstrated successful cases of his own. He found that brown fluorosis stains can permanently be removed by rubbing the enamel with an 18 percent HCl acid soaked cotton pellet wrapped around an amalgam condenser.

Two years later Croll and Cavannaugh developed a similar technique that involves pressure application of 18 percent HCl with pumice to achieve color modification. This was called the Enamel Microabrasion technique. The chief mechanism of stain removal would be limited to enamel abrasion, rather than enamel dissolution by the acid. Dr. Croll believed that the acid abrasive action of the compound gives the enamel surfaces, a super fine polish as a microscopic layer of enamel is removed. The freshly polished surface then develops a shiny glass like texture, resembling a highly polished microfilled composite resin restoration, as the tooth subsequently remineralized.

Jacobsson-Hunt (1988) reported that 30-second applications of the acid abrasive compound using a mandrel and gear reduction handpiece on extracted human teeth resulted in a enamel loss of less than 200μm. In 1989, Kendell reported that 5 second application of HCl acid pumice mixture removes 46μm of enamel which should be considerably tolerable.

An important concern about the safety of the hydrochloric acid pumice abrasion procedure is the low viscosity and high concentration of 18 percent HCl. To eliminate this problem and ensure safety of this technique, the viscosity of the acidic solution is increased by mixing 18 percent HCl acid with quartz particles so that the solution takes on a water soluble gel like form. This came to be known as the Modified 18 percent HCl acid Quartz-Pumice Abrasion technique.

The procedure was as follows:

1. The gingiva was protected by a layer of petroleum jelly.
2. The involved teeth were isolated with rubber dam.
3. After the teeth were dried with air, the paste which consisted of 18 percent HCl acid quartz-pumice particles, was applied with a cotton tip applicator to the stained areas of enamel.
4. The paste was allowed to remain for 5 seconds and then for 10 seconds. The enamel microabrasion was effectuated with a cotton swab pressure.
5. After 10 seconds, a marked degree of success was obtained and the stain was removed.
6. After 15 seconds of treatment, the enamel of the teeth turned to a normal shade.
7. At the end of the treatment, the teeth were washed and dried before removal of rubber dam and neutralized with a neutral sodium gel.

In this procedure, the quartz particles convert the acid into a gel form and function as additional abrasive agent. Six months follow-up of this treatment on several patients showed that the objectives of the treatment were achieved.

The advantage of this technique is that it is relatively economical and involves no laboratory costs. Also, it is readily acceptable to children.

BLEACHING OF NON-VITAL TEETH

1. In office bleaching.
2. Out of office bleaching (walking bleach technique).
3. Other bleaching techniques.

General procedures: Preparation of the affected non-vital teeth:

- Isolation is done with a rubber dam.
- The tooth is meticulously cleaned internally.
- Establish a lingual opening of sufficient size to provide access to the pulp chamber and orifice of the root canal.
- A slowly rotating bur is used to remove debris and a surface layer of dentin within the pulp chamber.
- The root canal filling material should be removed to a depth of 2-3 mm apical to the cervical line.
- Zinc polycarboxylate cement, Cavit or zinc oxyphosphate cement can be used to refill, 1-2 mm coronally to the CEJ.

Bleaching should never be attempted on any tooth that does not have a complete seal in the root canal. The agent can escape through a porous root canal filling and cause the patient extreme discomfort as well as possible loss of tooth.

Surface stains visible on the inside of the preparation are removed and the entire preparation is swabbed with chloroform or acetone to dissolve any fatty material and facilitate the penetraton of the bleaching agent into the tubules.

1. In-office Bleaching (Thermocatalytic Techniques)

- The pulp chamber is filled loosely with cotton fibers and the labial surface is covered with a few strands of cotton fiber to form a matrix for retaining the bleaching solution.
- This is saturated with 35 percent H_2O_2 using a glass syringe fitted with a stainless steel needle. The solution should be discharged slowly to saturate the cotton inside the pulp chamber and on the labial surface. Excess should be wiped immediately.
- A thin tapered tip from a single tooth bleaching instrument can be inserted into the pulp chamber. The heated tip is exposed for 5 minutes, in a sequence of 1 minute on and 15 seconds off.
- It has been established by Caldwell that a non-vital tooth can be treated to a temperature of 73°C without causing the patient any discomfort.
- An alternative to activate the H_2O_2 is the use of light and heat from a powerful light. The tooth is subjected to 6, 5 minute exposures while replenishing the bleaching agent at frequent intervals.
- The heating instrument and cotton can then be removed. Repeat the above process 4-6 times or for 20-30 minutes, each time placing new cotton fibers.
- This technique can be used alone or in combination with walking bleach.

2. Out of Office Bleaching (Walking bleach) (Figs 21.23 to 21.28)

- First described by Nutting and Poe in 1963.
- This procedure consists of filling the prepared chamber (as described previously) with a paste consisting of 35 percent H_2O_2 and sodium perborate. (Their effect is thought to be synergistic).
- Sodium perborate is a white powder which decomposes into sodium metaborate and H_2O_2 releasing oxygen. When mixed into a paste with Superoxol, this paste decomposes into sodium metaborate, water and oxygen.

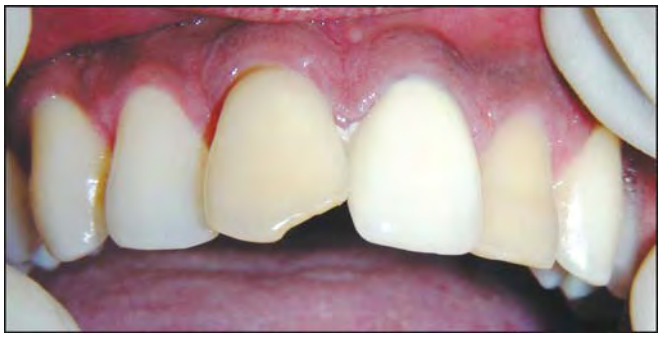


Fig. 21.23: Preoperative photograph

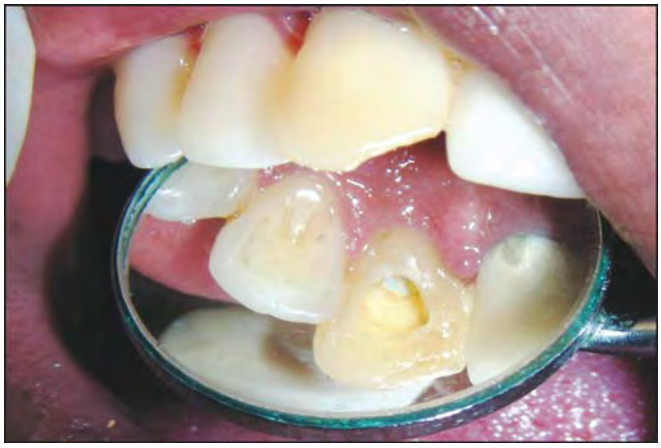


Fig. 21.24: Removal of the temporary restoration

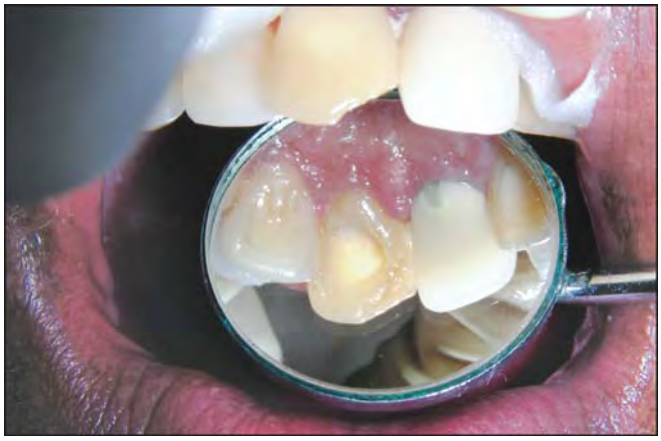


Fig. 21.25: Coronal barrier of GIC placed

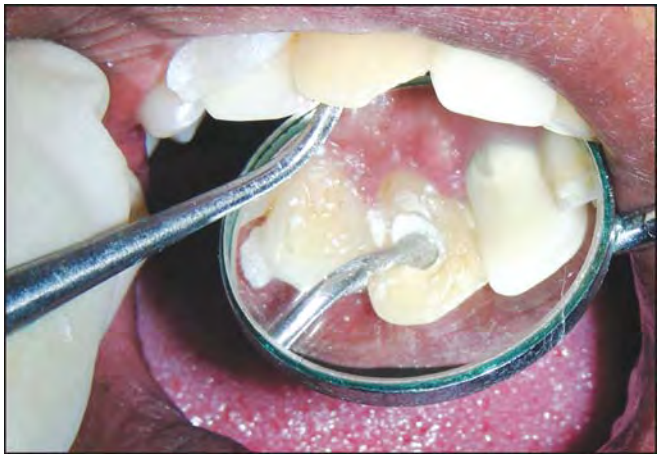


Fig. 21.26: Mixture of sodium perborate and superoxol placed

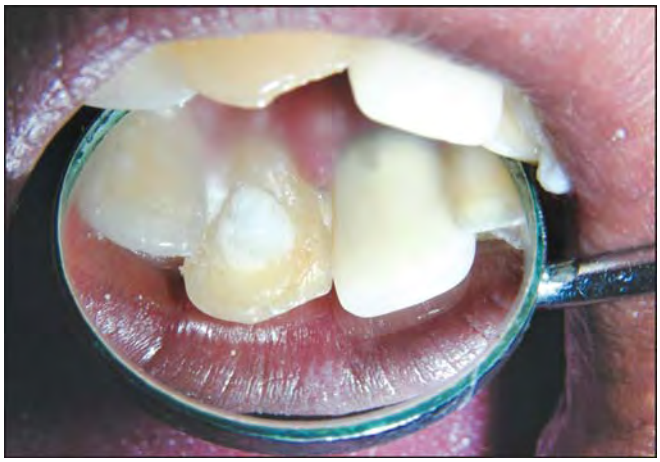


Fig. 21.27: Orifice sealed with temporary restorative material

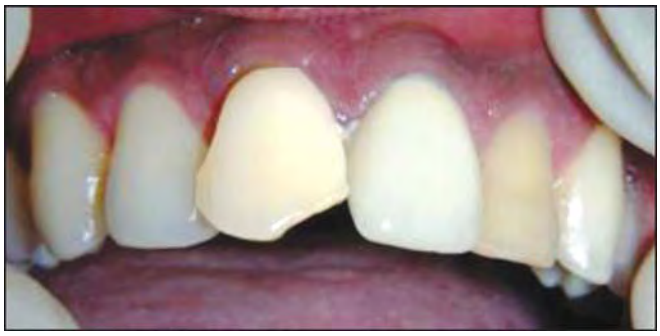


Fig. 21.28: Postoperative photograph

- When sealed into the pulp chamber, it oxidizes and discolores the stain slowly, continuing its activity over a long period.
- A small pledget of cotton wool is placed on the paste and the cavity is sealed with polycarboxylate cement kept under pressure till the cement sets.
- The maximum bleaching is attained 24 hours after treatment.
- The patient should return in 3-7 days.
- If the shade is still dark, then procedure should be repeated.
- If adequately light, then permanent restoration with GIC or composite resin is indicated.
- Generally two treatment sessions are required, although in some cases one session is sufficient.

3. Other Methods of Non-vital Bleaching

a. *Inside-outside bleaching* (Leonard and Stettembrim et al 1997)
   - Fabrication of a study model.
   - Light cured composite is placed on the model of the tooth or teeth to be treated. This acts as a reservoir to be created in a vacuum processed mouthguard whose thickness usually varies from 0.20 to 0.30 inch.
   - Mouthguard trimmed at the cervical margins on the labial and lingual portions and tried in the patient's mouth.
   - The gutta percha in the root canal is sealed off from the pulp chamber with GIC or resin modified GIC.
   - Patient is taught how to inject 10 percent carbamide peroxide into the canal orifice and into the mouthguard with a syringe.
   - Excess carbamide peroxide gel can be removed by brushing or using a paper tissue.
   - The patient may either sleep with the gel or remove the mouthguard after 1 or 2 hours. If the patient prefers the latter, it will take a few days longer.
   - At the end of the daily treatment, patient rinses his or her mouth and then places a cotton pellet to prevent food from getting into the opening.
   - An explorer can be used by the patient to remove the cotton pellet before the next procedure.
   - The total treatment proceeds and concludes rapidly with the results in as few as 3 or 4 days.

b. Anderson Takeo Hara, and LAF Punenta (1999) used a technique (suggested by Spassier) where sodium perborate and water were used for walking bleach technique instead of H_2O_2 to prevent cervical resorption. Sodium perborate broke down to sodium metaborate and H_2O_2. Two year results were satisfactory with this technique.

Intentional Endodontics and Intracoronal Bleaching

- 1982 - Abou-Rass
- Treatment modality for severe tetracycline stains
- Not followed presently
- 1998-Follow-up report with permanent esthetic results.

In-Office-Power Bleaching

Power bleaching is a term given to accelerated, in-office tooth whitening procedures using either a Xenon plasma arc curing light or a Laser

- Liquid rubber dam.

Advantages

- Time factor.
- Avoids problems of home bleaching.

Disadvantages

- Caustic nature of 35-50 percent hydrogen peroxide
- Increased in office time.
- Dehydration of teeth resulting in false light shade.
- Expensive.

Over the Counter Systems (Fig. 21.29)

The Trayless Approach to Tooth Whitening:

The new whitening product, "Crest Whitestrips" consists of a thin, flexible strip coated with an adhesive hydrogen peroxide whitening gel. The flexibility of the strip allows it to conform to the tooth surface and provide uniform, intimate contact of the whitening gel for the 30-minute wear period.

The strips are made of 9 µm polyethylene and embossed with small reservoirs 0.13 cm in diameter and 0.015 cm in depth. The embossing provides capacity to hold the gel and also improves the conformability of the strip to the tooth surface (Fig. 21.30). The strip device provides a uniform, consistent amount of whitening gel to the tooth surface and protects the gel from salivary interaction during the whitening process. The thinness of the strip makes it almost unnoticeable during the wear period.

Two different strip designs are used to whiten the dentition-one for the maxillary dentition and one for the mandibular dentition.

The maxillary strip is rectangular with rounded corners and measures 6.5 cm long × 1.5 cm wide The maxillary strip is loaded with 0.200 g of the adhesive whitening gel and contains approximately 11 mg of hydrogen peroxide, providing delivery of approximately 1.1 mg hydrogen peroxide per square centimeter of contact.

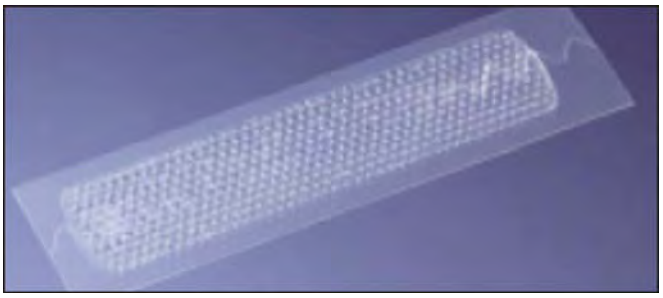


Fig. 21.29: Bleaching strips

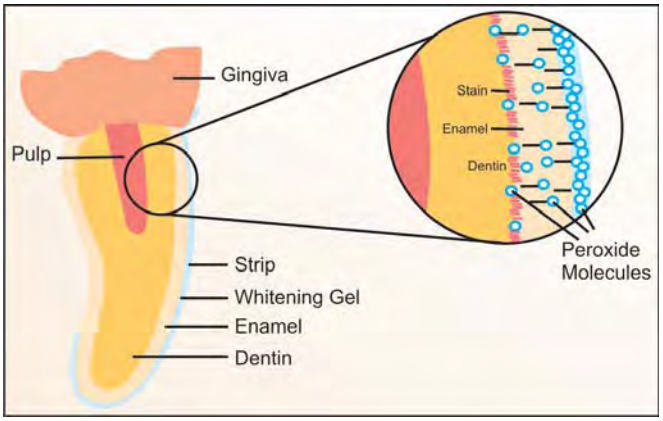


Fig. 21.30: Bleaching by whitening strips

The mandibular strip is trapezoidal with rounded corners and measures 5.0 cm long × 2.0 cm wide.

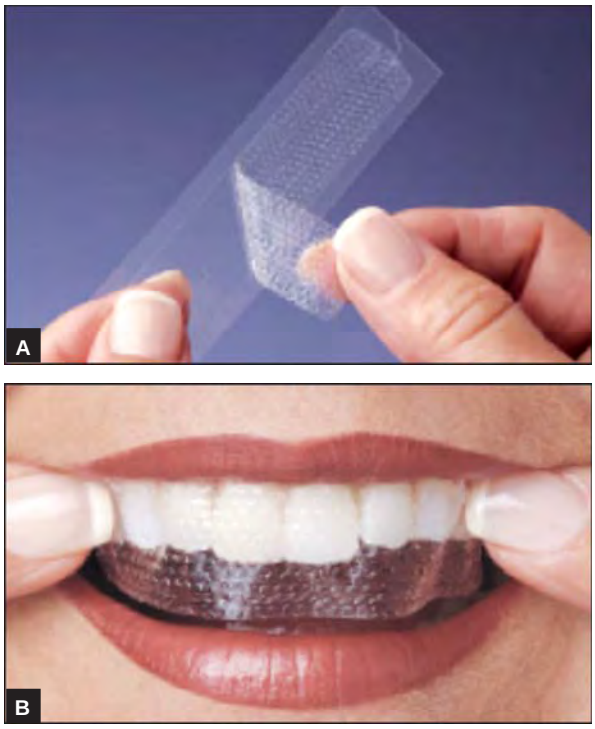
It is loaded with 0.150 g of adhesive whitening gel and contains approximately 8.3 mg of hydrogen peroxide, providing delivery of approximately 1.1 mg hydrogen peroxide per square centimeter of contact-the same dose per unit area as the maxillary strip.

Each preloaded strip is individually presented on a release liner. To use the product, the strip that holds the gel is peeled off the release liner (Fig. 21.31).

Bleaching Lights (Fig. 21.32)

Conventional bleaching lights:

- Enhance the bleaching action of hydrogen peroxide simply by adding heat
- Slow and uncomfortable to the patient



Figs 21.31A and B: Bleaching strips application

Metal halide lamps
Require 20 mins passes, provide heat.

Tungsten-Halogen curing light:
- Curing light provides heat
- Time consuming process (40-60 sec/tooth)

Xenon Plasma arc light (Power Bleaching)
- Non-laser, high-intensity light produces a great deal of heat.

Advantage

Very fast 3 sec/tooth.

Disadvantage

Thermal trauma to the pulp and surrounding soft tissues.

Clinical Measurement of Tooth Whitening

A number of methods are available for measuring the color of teeth preoperatively and the color changes undergone during tooth whitening procedures. One of the most common methods is the simultaneous comparison of the tooth with a standard shade guide. This has been used in a large number of tooth whitening studies where longitudinal changes in tooth color have been measured. It is a subjective method and a number of factors can influence this process. For examples, lighting conditions, experience, age, fatigue of the human eye, make-up, room decor and color blindness. Therefore, care must be taken to standardise and control these factors.

Fig. 21.32: Bleaching light

Colorimeters are instruments designed to measure the color of objects. The color is often expressed in terms of the Commission Internationale de l'E′ clairage (CIE) Lab color space. The CIE Lab color space represents a uniform color space, with equal distances corresponding to equal perceived color differences. In this three-dimensional color space, the three axes are L*, a* and b*. The L* value is a measure of the lightness of an object and is quantified on a scale such that a perfect black has an L* value of zero and a perfect reflecting diffuser an L* value of 100. The a* value is a measure of redness (positive a*) or greenness (negative a*). The b* value is a measure of yellowness (positive b*) or blueness (negative b*). The a* and b* co-ordinates approach zero for neutral colors (white, grays) and increase in magnitude for more saturated or intense colors. The use of a colorimeter to measure tooth color in vivo requires the fabrication of a custom positioning jig to ensure reproducible intra-oral positioning of the instrument's aperture onto the tooth surface.

Another approach for measuring tooth color is by using non-contact camera-based digital imaging and analysis systems. Typically, an image of the anterior teeth is captured under controlled lighting conditions by a digital camera, together with suitable calibration tiles or standards, and then subsequently analyzed via computer software to determine the color of the individual teeth, often expressing them in terms of CIE Lab values. For example, after 14 days use of a 10 percent carbamide peroxide tray-based system, the mean change from baseline in L* and b* were 2.07 and 1.67, respectively.

Factors Influencing Tooth Whitening

Type of Bleach

The majority of contemporary tooth whitening studies involve the use of either hydrogen peroxide or carbamide peroxide. In general, the efficacy of hydrogen peroxide containing products are approximately the same when compared with carbamide peroxide containing products with equivalent or similar hydrogen peroxide content and delivered using similar format and formulations.

An alternative source of hydrogen peroxide is sodium percarbonate and this has been used in a silicone polymer containing product that is painted onto the teeth forming a durable film for overnight bleaching procedures.

A tooth bleaching system based on sodium chlorite applied to the tooth surface and activated under acidic conditions has been described in the literature, Similarly, other potential vital tooth bleaching systems have been outlined in the literature with limited supporting evidence for their efficacy. These include peroxymonosulphate, peroxide plus metal catalysts and oxireductase enzymes. The long-term acceptability and relative efficacy of these alternative tooth bleaching systems requires significant further research.

Concentration and Time

Two of the key factors in determining overall tooth whitening efficacy from peroxide containing products are the concentration of the peroxide and duration of application. Sulieman et al compared the in vitro tooth bleaching efficacy of gels containing 5-35 percent hydrogen peroxide and found that higher the concentration, lower the number of gel applications required to produce uniform bleaching.

Heat and Light

The rate of chemical reactions can be increased by increasing the temperature, wherein a 10°C rise can double the rate of reaction. The use of high-intensity light, for raising the temperature of the hydrogen peroxide and accelerating the rate of chemical bleaching of teeth was reported in 1918 by Abbot.

Complications of Internal Bleaching

1. *Cervical resorption*
   - Possible mechanism is that H_2O_2 percolates from the access cavity to the root surface through the acid treated patent dentinal tubules.
   - This stimulates an inflammatory response leading to dentin resorption.
   - Alternative theory - bacteria that have leaked into the pulp chamber from the gingival crevice via the dentinal tubules or directly from the access cavity may cause resorption.
   - Root resorption can be arrested by placing CaOH in the chamber.
2. *Spillage of bleaching agents*
   - Oxidizing agents are safer to handle as a paste than in a solution.
   - Rubber dam application is a must.
   - Any spillage must be diluted immediately with copious volumes of water.
3. *Failure to bleach*
   Causes:
   - Commonest is discoloration by metal ions in silver amalgam.
   - Incomplete removal of composite resin or GIC, which prevents the bleaching agents to penetrate into dentinal tubules.
   - H_2O_2 which has passed its expiry date or improperly stored.
4. *Over bleaching*
   - Recommended by certain authors as the tooth may darken with time and assume desired shade.
   - However, it is important not to over bleach. Therefore, ask the patient to monitor color and return in case of over bleaching.

5. *Brittleness of tooth crown*
   - Bleaching causes the coronal tooth structure to be brittle. This may be caused due to removal of all the discolored dentin rather than using the bleaching agents to discolor the dentin.

c. *Laser assisted bleaching (Fig. 21.33)*
   - One company uses the argon laser with a wavelength of 488 nm for 30 second to accelerate the activity of its bleaching gel. After the laser energy is applied, the gel is left in place for 3-4 minutes and then removed. This procedure is repeated 4-6 times.
   - Another product uses Ion Laser Technology. The argon laser is used as previously described.

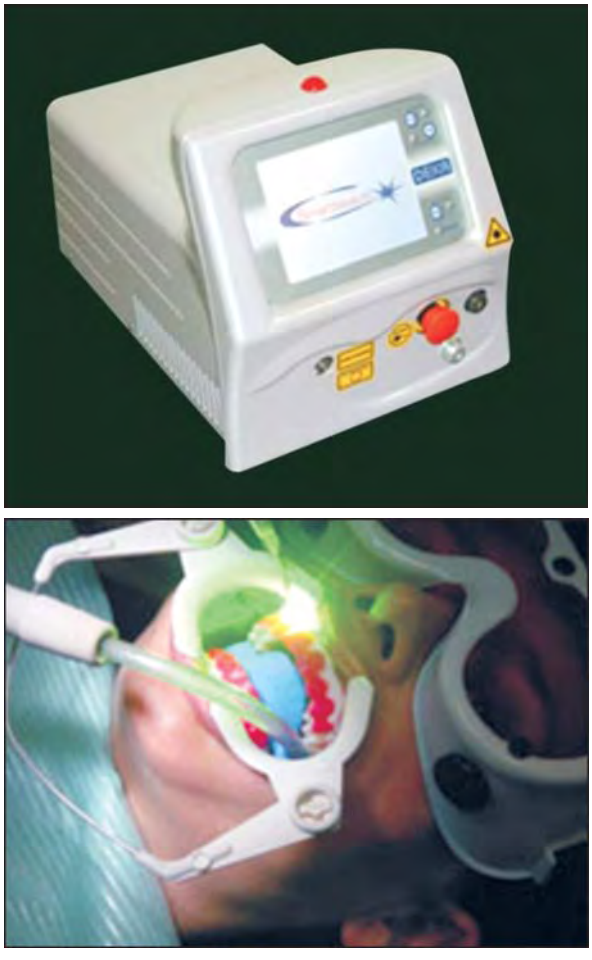
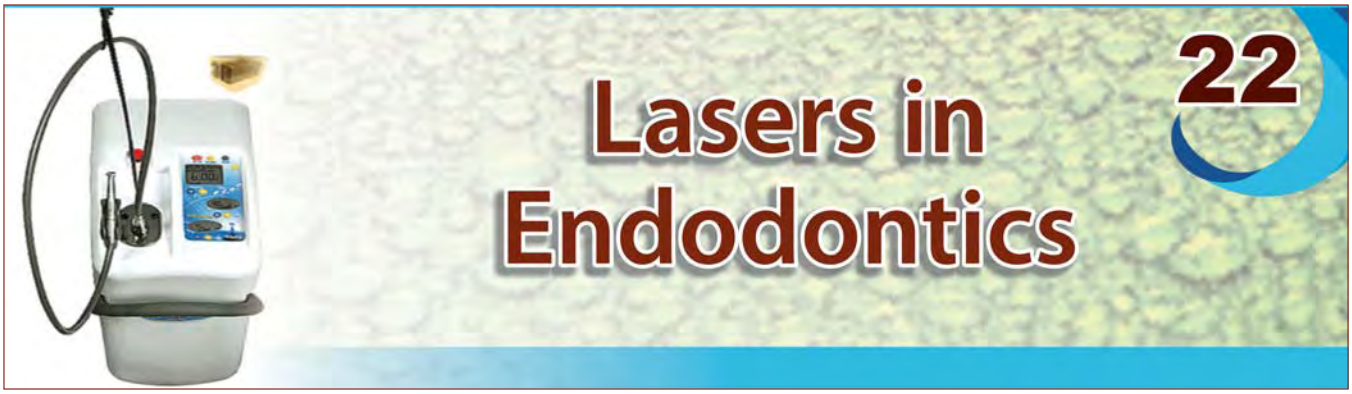


Fig. 21.33: Laser bleaching

Then the CO_2 laser is employed with another peroxide solution to promote penetration of the bleaching agent into the tooth to provide bleaching below the surface.
   - Argon laser energy is in the form of a blue light and is absorbed by the dark color. It seems to be the ideal agent to be used in tooth whitening when used with 50 percent H_2O_2 and a patented catalyst. The affinity to dark stains ensures that the yellow-brown colours can be easily removed.
   - The CO_2 laser has no colour requirement. It is unrelated to the colour of the tooth. Energy is emitted, in the form of heat. It is invisible and penetrates only 0.1 mm into water and H_2O_2, where it is absorbed. This energy can enhance the effect of whitening after the initial argon laser process.

SUGGESTED READING

1. "A technique for bleaching non-vital teeth." Leonard Settembrim et al, JADA, 1997 September, 1283-85.
2. "An atomic force microscopy study on the effect of bleaching agents on the enamel surface." C Hegedus et al, J Dent, 1999;27:509-15.
3. "Bleaching teeth" Ronald Feinman, Ronald Goldstein and David Garber, Quintessence Publishing Co. Inc., 1987.
4. "Bleaching teeth: New materials - new role." Ronald E. Goldstein, JADA, 1987;43-52.
5. "Estimation of dissolution of calcium by Old McInnes and New McInnes solution." Nageswar Rao R and Nangrani V, Endodontology 1998;50-53.
6. "Enamel microabrasion: The technique." Croll T.B., Quint. Int., 1989;20:395-400.
7. "History safety and effectiveness of current bleaching techniques and applications of the night guard vital bleaching technique." Haywood Van B., Quintessence Int., 1992;23 :471-88.
8. "Historical development of Whiteners: Clinical safety and efficacy." Van B. Haywood, Dental Update, 1997 April.
9. "Laser assisted bleaching: An update." JADA, 1998;129:1484-87.
10. "Non-vital tooth bleaching: A 2 year case report." AT Hara, LAF Pimenta, Quintessence Int., 1999;30:748-54.
11. "The effectiveness of a modified hydrochloric acid quartz-pumice abrasion technique on fluorosis stains: A case report" Gamze Erdogan, Quint. Int., 1998;29:119-22.



LASER: LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION

Over the years, the researchers are continually investigating the laser applications in dentistry. The first laser used in dentistry was reported by Weichman and Johnson in 1971 who attempted to seal the apical foramen in vitro by means of high power infra-red laser. Although their goal was not achieved, sufficient relevant and interesting data were obtained to encourage further study. Since then many papers on laser applications in dentistry have been published with growing interest in the topic.

Fig. 22.1A: Waterlase used in RCT

In endodontics in particular acceptance of this technology by clinicians has remained limited, perhaps partly due to the fact that this technology blurs the border between the technical, biological and dental research (Figs 22.1A and B).

Lasers used in dentistry have emission wavelengths that range from 0.5 to 10.6 microns. They lie in either the visible or infrared, non-ionizing portion of the electromagnetic spectrum. Hence, they emit either a visible wavelength of light or an invisible infrared light. Excimer lasers fall in the UV region.

Laser medium consists of a resonant cavity with a power supply, a cooling system, and with control system to the unit. Lasers are named after the chemical elements, molecules or compounds that comprise the core or the active medium, that is stimulated. The active medium can be a container of gas as in case of CO_2 laser a solid crystal rod such as an Erbium:YAG laser, or a solid state electronics in case of a diode laser.

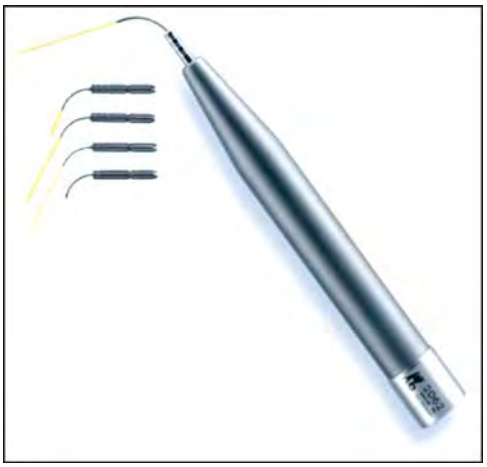


Fig. 22.1B: LASER Endo Tips

Stimulation for the production of laser is usually a beam of white light from a flash lamp or arc lamp, or monochromatic light from another laser; or it may be electric current in case of diode laser.

EMISSION MODES AND DELIVERY

Lasers emit light energy in three different basic modes.

A. Continuous mode: the beam is emitted continuously at one power level for the length of the time operator presses the foot switch.
B. Gated -pulse mode: laser energy is switched on and off like a strobe light by opening and closing the mechanical shutter in front of the beam path of a continuous wave every few milliseconds.
C. Pulsed mode: large energies are emitted for a short time, of a few microseconds usually, followed by a long time when the laser is off.

Lasers utilize different delivery systems, depending on the wavelength of the laser and the access required at terminal target tissue. These include:

A. *Articulated arms:* These have joints that allow the arm to bend, made of tubes connected at joints where a mirror reflects a beam into center of the next tube without touching the inner surface of the tube.
B. *Hollow waveguide:* this is a flexible hollow tube that has an interior mirror finish the laser energy is reflected along this tube and exits through handpiece. These are much thinner than the articulated arms.
C. *Glass fiberoptic cable:* This is more flexible than a waveguide, smaller in diameter, with sizes ranging from 200 to 600 microns. Quartz optical fiber encased in a resilient sheath.

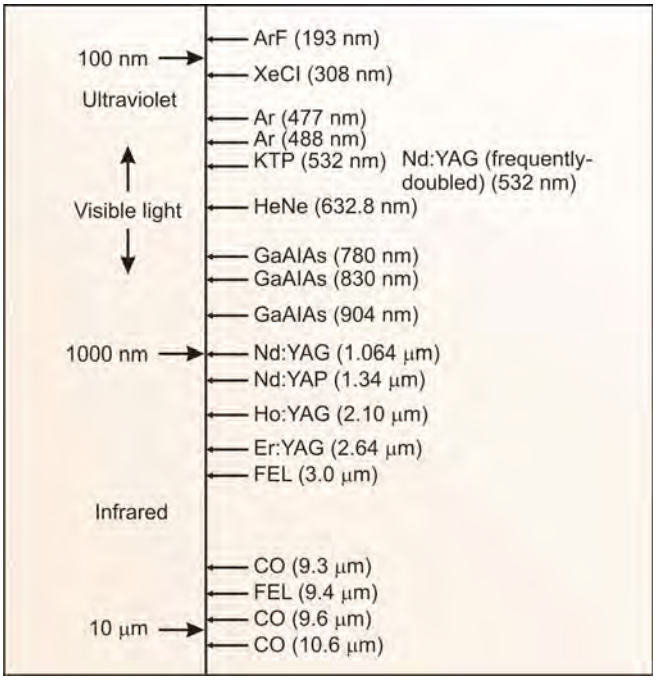
Wavelength of laser determines the modes of delivery as fiberoptic cables are not efficient at transmitting all wavelengths. Wavelengths of 300 nm to 2400 nm are efficiently transmitted by fiberoptic cables; whereas wavelengths above 2400 nm and below 300 nm are absorbed by quartz fiber and laser energy is converted into mere heat. Hence CO_2 laser energy at a wavelength of 10,600 nm is absorbed after only a few millimeters traveling through optic cable.

INTERACTION OF LIVING TISSUE WITH THE LASERS

Laser can interact with tissues in four basic ways.

A. *Reflection:* Off the surface without penetration or interaction of light energy with the tissue.
B. *Transmission:* Apportion of light may be transmitted through the tissue unchanged as if transparent to laser beam.
C. *Absorption:* Some of the light may be absorbed into a component of the tissue in which case there will be transference of energy to the tissue.
D. *Scatter:* The remaining light may penetrate the tissue and be scattered without producing noticeable effect on the tissue.

SPECTRUM AND WAVELENGTHS OF LASERS



LASERS USED IN ENDODONTICS

1. Gallium-Aluminum (GaAlAs) Semiconductor Diode Laser
2. Helium-Neon (HeNe) Lasers
3. Nd: YAG Laser
4. Er: YAG Laser
5. Er, Cr: YSGG Laser
6. CO_2 Laser
   i. *Gallium-Aluminum (GaAlAs) Semiconductor Diode Laser*: Previous studies on semiconductor diode laser irradiation of dental pulp have reported no dental pulp damage High-power semiconductor lasers of 3 to 30 W have been developed, however, and soon will be applied to dental pulp treatment. To confirm the effect on dental pulp of high-power semiconductor diode lasers, histopathologic examination must be performed.

ii. *Helium-Neon (HeNe) Lasers:* The commercial HeNe lasers of more than 15 mW have not been used for dentistry. There is no possibility of dental pulp tissue damage by this laser.

iii. *Neodynium Yttrium Aluminum Garnet (Nd: YAG) Laser:* Because the Nd: YAG laser has a wide energy emission range, the clinician should take into careful consideration such parameters as the:
   1. Exposure time
   2. Power
   3. Whether the laser emission is continuous or pulsed
   4. The type of laser tip
   5. Distance between the laser tip and the surface to be irradiated.

   The characteristics of the individual target teeth must be considered at the time of laser therapy. For example, whether the tooth surface is enamel or dentin, the thickness between the carious surface and the pulp chamber, and the color of the target area all must be taken into consideration. Dental pulp tissue irradiated at 3 W and 20 pps for 0.5 second, at 2 W and 20 pps for 1 second, and at 1 W and 20 pps for 2 seconds by the pulsed Nd: YAG laser (ADL 300, ADL Inc., Chicago, IL) showed no adverse effects. When black India ink was applied to the tooth surface and laser irradiation was conducted at 2 W and 20 pps for 1 second, the temperature rise of the pulp chamber was less than 3°C and completely disappeared after 5 seconds. Laser anesthesia of dental pulp, sedative treatment of temporo-mandibular arthrosis, and laser acupuncture therapy as well as treatment of the hypersensitive dentin can be performed without producing dental pulp damage, severe pain or tissue burn.

iv. *Carbon dioxide (CO_2) Laser:* The CO_2, laser, similar to the Nd:YAG laser, can emit high energy. The dental pulp tissue is affected by parameters such as waveform, power, and time of laser exposure. The wavelength of the CO_2 laser is easily absorbed in water. However, there is little carbonization or heat penetration on the surface of substances that contain water. If the substance contains no water, carbonization and crack formation occur easily on the surface of the substance. CO_2 laser also is used for ablating dental pulp tissue and soft dentin. When ablating carious enamel and dentin, pain and pulp damage may occur depending on the laser power, the exposure time, and the wetness of the surface. Generally the CO_2 gas laser should be used at less than 1 W for less than 1 second under anesthesia and under air cooling. If the tooth is treated under these conditions, dental pulp damage and postoperative pain may be avoided.

v. *Er: YAG Laser:* The 2.940 μm wavelength of the Er:YAG laser makes it possible to ablate hard and soft tissue under water spray. Previous investigators have reported no pulp damage if the cavity preparation is carried out under copious water spray. It is necessary, however, to spray water mist just under the hard tissue surface that is to be ablated by laser.

vi. *Er Cr: YSGG Laser:* The ErCr:YSGG laser also can be used to ablate hard and soft tissues because the wavelength is 2.780 μm, which is similar to that of the Er:YAG laser. It has been reported that dental pulp damage can be prevented if cavity preparation is performed under sufficient water spray. Too much water decreases the ablation ability of this laser, however.

vii. *Argon Laser:* The argon laser can be used to cure composite resin quickly. This laser also can be used to ablate soft tissue. Dental pulp damage may be avoided if laser irradiation is performed for a short time at 1 W, while maintaining the laser tip at a distance of approximately 10 cm from the tooth surface.

The following is a summary of the laser applications in endodontics investigated over the years.

DESENSITIZATION OF HYPERSENSITIVE DENTIN AND TEETH BY LASER STIMULATION

Laser Devices, Techniques, Assessments and Mechanisms

Semiconductor Diode Laser

Various 30 mW GaAlAs semiconductor laser devices have been commercially developed for desensitization treatment. After drying the hypersensitive dentin as much as possible, the laser tip is placed in direct contact with the tooth surface, which is then irradiated for a period of 30 seconds to one minute. If the desired

effect cannot be obtained, the treatment is carried out once after a couple of days. A shorter exposure time and, effectiveness are expected for the 3-W and 20-W semiconductor laser. Mechanism of pain reduction by the laser stimulation is thought to be clarified by electrophysiologic and laser transmission studies. These studies indicate local changes around the dentin and the nerve endings as well as changes in the central pulpal neuron.

HeNe Laser: A treatment method similar to that of semiconductor diode laser is used with 6-mW and 15-mW HeNe lasers. The clinical assessment and mechanism are thought to be identical to those of the semiconductor diode laser.

Pulsed Nd: YAG Laser

Laser stimulation is performed at the points of the same side as that of the tooth pain at 2 W and 20 pps for 1 to 2 minutes at about 10 cm. Exposure time should be only 10 seconds. With respect to clinical assessment, in cases of slight or mild pain, the percentage of reduction is 90 to 100 percent. In cases of severe pain, the percentage of pain reduction is less than 60 percent, however. The mechanism of pain reduction is to be the same as that for the semiconductor laser.

Stimulation method for the surface of dentin hypersensitivity: The laser parameter must be changed according to the degree of pain induced by air blast or tactile examination using an explorer. Laser parameters of 1 W and 20 pps for less than 0.1 second with black ink are recommended for this treatment. This method should be applied only after sufficient training and only after all other laser treatments have been tried. Assessment by this method shows the most effective results because of the morphologic changes produced in the dentin and the stimulation of the central pulpal neurons.

CO_2 Laser

The effectiveness of this technique is less than that of the pulsed Nd:YAG laser, and the laser exposure technique is difficult to perform without inducing pain. Usually the laser is used at 0.5 to I W, and the end of the laser tip is moved quickly, maintaining a distance of 10 cm from the tooth surface for a couple of minutes, until the pain induced by an air blast disappears completely.

Stimulation Method on the Tooth Crown Surface

Carbon dioxide laser exposure must not be done on the dried tooth crown surface because not only pain, but also carbonization is induced. Sodium fluoride paste or petroleum jelly is coated on the tooth surface, and then the tooth surface is exposed to the CO_2 laser to prevent the occurrence of pain and the carbonization on the tooth surface by the laser. Output powers used for the treatment ranged from 0.5 to 3 W, and a success rate of greater than 90 percent was reported.

Stimulation Method for the Surface of Dentin Hypersensitivity

Although this method is not recommended, it is not so difficult to perform if the laser exposure is done at 0.5 W under air cooling after painting sodium fluoride paste on the surface. A caries prevention effect is derived by laser irradiation with sodium fluoride paste on the exposed dentin surface. This method offers the highest effectiveness with pain reduction of dentin hypersensitivity of the three above-mentioned CO_2 laser methods.

APPLICATION OF LASER IN INDIRECT PULP CAPPING

As lasers were introduced to dentistry, nobody thought that laser could perform the treatment of indirect pulp capping. The discovery of closure of dentinal tubules by laser energy and the sedative effects on pulpitis has led to the development of several new treatments that are soon to be put into practice.

Deep cavities, hypersensitive cavities, and cavities that require sedative treatment are some of the indications for this treatment.

The outcome of pulp capping procedure whether direct or indirect is unpredictable and success rates ranging from 44 to 97 percent have been reported.

When using the pulsed Nd:YAG laser, it is necessary to combine the application of black ink to the tooth surface and air spray cooling to prevent dental pulp damage resulting from the laser energy provided by 2 W and 20 pps for less than 1 second on the area.

Wound healing of the irradiated pulp seemed to be better than that of controls at 1 week and dentin

bridge formation in the irradiated pulp was stimulated at 4 to 12 weeks after operation using Nd:YAG laser (Ebihara 1989).

The mechanism of this treatment has been proved by various studies that described the degree of dye penetration as having decreased after laser irradiation of the dentin surface. The mechanism of sedation by the laser is thought to be identical to that of sedation of dentin hypersensitivity.

When using the CO_2 laser, the dental tissue must not be irritated by exposure to high-energy lasers for long periods of time. In some cases, it is recommended that this laser be used with 38 percent silver ammonium solution.

However according to a study conducted by S Jukie et al in 1997, no newly formed dentin was found over the exposed pulp tissue in the root canal openings 30 to 45 days after CO_2 and Nd:YAG laser irradiation.

APPLICATION OF LASER IN DIRECT PULP CAPPING

As laser treatment has advantages with respect to control of hemorrhage and sterilization, laser use for direct pulp capping has attracted dentists' attention. Previous researchers reported that the indications for direct pulp capping are extremely limited. The diameter of pulp exposure must be 2 mm or less, and there must be no infection in the pulp. Further, research on this subject is anticipated.

When using the CO_2, laser for this treatment, laser irradiation of the exposed dental pulp must be performed to stop bleeding and sterilize the area around the exposure. Laser irradiation should be performed at I or 2 W irrigating alternatively with 8 percent sodium hypochlorite and 3 percent hydrogen peroxide, for not more than 5 minutes.

Calcium hydroxide paste must be used to dress the exposed pulp after the laser treatment, after which the cavity should be tightly sealed with cement such as carboxyl ate cement. Final filling of the cavity is done after 6 months.

The high success rate is thought to be due to control of hemorrhage, disinfection, sterilization, carbonization, and stimulation effects on the dental pulp cells. It causes scar formation in the irradiated area due to thermal effects which may help to preserve the pulp from bacterial invasion.

In addition, the laser minimizes the formation of hematoma between the pulp tissue and the calcium hydroxide dressing allowing a close contact between the dressing and the exposed pulp.

If Melcer's description of therapy for inflamed pulps with lasers is found to be valid, the indication of this treatment may become more widespread in the future.

LASER ABLATION AND ACCESSORY TREATMENT FOR VITAL PULP AMPUTATION

Vital pulp amputation by laser therapy was one of the most highly anticipated laser treatments in endodontics because this treatment appeared to offer amputation of the pulp tissue at a satisfactory level. Control of hemorrhage and amputation of pulp tissue without producing pulp damage was not always easy in narrow root canals.

Previously CO_2 laser was commonly used for pulp capping and amputation procedures. Even though it is possible to use only the CO_2 laser, this requires significant time, and the pulp tissue may be damaged by the laser energy. A CO_2 laser technique is carried out only for pulpal hemostasis,after which pulp amputation with an excavator or a bur is recommended.

When it is necessary to ablate the pulp tissue into the apical portion of the root canal, several laser exposures are required. As a result, the carbonization layer formed on the surface of the pulp tissue by the laser energy must be removed by irrigating alternatively with 3 percent hydrogen peroxide and 5.25 - 11 percent sodium hypochlorite.

Pulsed Nd:YAG laser should be used only for pulpal hemostasis, sedation orand inflammatory effects, and stimulation of the remaining pulpal cells but not for vital pulp amputation instead of an excavator or burs as heat produced by this wavelength damages the pulp tissue. The HeNe and low-power semiconductor diode lasers are alternative lasers for these purposes.

ACCESS CAVITY PREPARATION AND ENLARGEMENT OF THE ROOT CANAL ORIFICE BY LASER

Currently Access cavity preparation has been performed by air turbine, and enlargement of the root

canal orifice has been carried out using a Peeso reamer or a Gates Glidden drill or bur.

The Er: YAG and ErCr: YSGG laser, which ablate enamel and dentin, have been developed and improved. As a result, these lasers may soon replace the air turbine, Peeso reamer, and Gates Glidden drill as the primary method of treatment. Vital extirpation of infected root canals is one indication for these lasers. In particular, this technique seems applicable for cases in which the Peeso and Gates Glidden instruments cannot be inserted into the tooth because of difficulty of opening the mouth and for cases in which it is difficult to find the root canal orifices.

A new type of ErCr:YSGG laser has been developed and put into practice. If this laser is applied for cutting enamel and dentin at 5 W and 6 Hz under water spray, access cavity preparation and enlargement of root canal orifices can be performed easily. The laser can be transferred via optical fibers inside the root canal.

Detailed examination must be done to prevent perforation into the periodontium and step formation on the root canal wall.

ROOT CANAL WALL PREPARATION BY LASER (FIG. 22.2)

A laser that can cut enamel and dentin with fine optical fibers has been developed, making it possible to remove pulp tissue and prepare root canals. Only straight and slightly curved canals are indications for applying this treatment. Equipment of Er:YAG laser at 8 Hz and 2 W produced by KaVo Co. (Ulm, Germany) to prepare root canals.

The laser tip must slide gently from the apical portion to the coronal portion, while pressing the laser tip to the root canal wall under water spray. During laser exposure of the apical portion at more than 1.0 mm from the root apex, the debris at the apical foramen must not be pushed into the periapical tissue. When the laser fiber is unable to be inserted into root canals, the laser treatment should be performed after carrying out the usual root canal preparation using reamers and files.

Various studies have shown the Er: YAG laser is capable of removing infected dentinal surfaces and the smear layer present after all forms of mechanical root canal treatment. For this purpose, the laser irradiation must be performed after or in combination with the usual root canal preparation.

Fig. 22.2: Root canal treatment using lasers

The orifices of the dentinal tubules are exposed facilitating a tight fitting root canal filling which is indispensable for a successful root canal treatment.

LASER APPLICATION FOR REMOVING PULP REMNANTS AND DEBRIS AT THE APICAL FORAMEN

The pulsed Nd: YAG laser was used for removing pulp remnants and debris that are deposited at the apical foramen. A power of 2 W at 20 pps for 1 second is recommended. A 5 second interval should be applied to the root canal wall or to the apical foramen.

The effects of this laser irradiation on the apical foramen include sterilization, removal of pulp remnants, control of hemorrhage, and stimulation of cells surrounding the root apex as well as debridement of the surface.

Harashima et al (1998) used argon laser on instrumented root canals for 2 sec at the area of apical seat. The laser was activated during withdrawal strokes from the apical to the coronal area of the root canal. Four exposures were made of 15 sec each. The results of this study showed that argon laser irradiation had reduced intracanal debris.

The laser irradiation produced melted dentin surfaces and vaporized the debris and pulpal tissue remnants. This was enhanced in presence of diamine

silver fluoride. Studies have shown that Er: YAG laser was more effective in removing the smear layer and debris on root canal walls than the argon or Nd: YAG laser. Potassium titanyl phoshate laser (532 nm) and argon fluoride excimer laser (193 nm) was able to remove smear layer and debris form root canal.

ROOT CANAL CLEANING AND IRRIGATION IN COMBINATION WITH IRRIGATORS AND LASERS

Some laser devices produce cavitation effects in root canals in a manner similar to that of the ultrasonic irrigator.

At present, the effect is weaker than that of ultrasonic irrigation. This laser technique is likely to be improved in the future. Straight and slightly curved root canals as well as wide root canals are indications for this treatment.

The pulsed Nd: YAG laser, Er:YAG laser, and Er,Cr:YSGG laser are recommended. A power of 2 to 5 W usually is used for approximately 2 minutes. The laser irradiation is not carried out by the laser alone; a solution such as 5.25 percent sodium hypochlorite or 14 percent ethylenediaminetetra-acetic acid (EDTA) also must be used.

STERILIZATION OR DISINFECTION OF INFECTED ROOT CANALS

The laser is an effective tool for killing microorganisms because of the laser energy and wavelength characteristics. To prevent thermal damage to the periodontium surrounding the tooth, various techniques are considered and recommended. Infected root canals are an indication for this laser treatment, but application to extremely curved and narrow infected root canals appears difficult.

Pulsed Nd:YAG , argon, semiconductor diode, CO_2, Er:YAG, and other lasers have been considered for use in this treatment.

The pulsed Nd:YAG laser has been recommended for this treatment because of the ease with which the laser energy and laser fiber can be controlled.

To increase the effect of sterilization in the infected root canal, we placed about 38 percent silver ammonium solution into the root canals and irradiated the canals using the pulsed Nd:YAG laser at 2 W and 20 pps for 5 second. 5.25 percent sodium chloride or 14 percent EDTA also has been used.

It is believed that it is impossible to sterilize the root canals completely without sterilizing the surrounding periapical tissue completely. In the future, lasers in combination with certain drugs may perform sterilization by the laser.

Chances of spreading bacterial contamination and dissemination from the root canal to the patient and the dental team via the smoke produced by the laser can be avoided by using strong vacuum pump system.

STRENGTHENING OF THE ROOT CANAL WALL USING A SILVER AMMONIUM SOLUTION AND THE LASER

Silver ammonium solution has been used in iontophoresis of infected root canals and in caries prevention by application to the primary caries.

Teeth lased with 38 percent silver ammonium solution became difficult to fracture. Pulpless teeth are indicated for this treatment.

The pulsed Nd:YAG, CO_2, semiconductor diode, and argon lasers are recommended as laser devices for this treatment. To prevent leakage of the 38 percent silver ammonium solution into the periapical tissue through the apical foramen, a cotton pellet should be infused with the solution and placed in the apical one third.

Usually this treatment is performed using a pulsed Nd:YAG laser at 2 W and 20 pps for 5 seconds in one root canal. If there are no clinical symptoms, root canal obturation is carried out. If clinical symptoms are present, however, the patient should be observed after dressing the root canal using calcium hydroxide paste.

Because no fine flexible fiber exists for use with the CO_2, laser, laser irradiation into the root apex is somewhat difficult.

CLOSURE OF APICAL FORAMINA OF ROOT CANALS BY LASER

If apical foramina of root canals are completely closed temporarily by laser beams, the result of endodontic treatment is changed drastically.

Anic et al have attempted this method, but no researchers have resolved all of the problems involved with its application. Preliminary studies performed revealed that closing small apical foramina was possible using the pulsed Nd:YAG laser.

Closure was attempted by combining light-curable composite resin and argon laser or combining

sectioned gutta-percha points and a pulsed Nd:YAG laser, However, it was found that it was relatively easy to close the apical root canal.

LASER TREATMENT UNDER A FIBERSCOPE

Laser treatment under a fiberscope has been performed for some time in stomach surgery. In the field of endodontics, treatment under a fiberscope has been put into practice in Japan as well as the United States.

By combining these instruments, dentists can remove debris, pulp remnants, root canal polyps, fractured instruments, and root canal filling materials with the aid of visual feedback.

Inspection of the prepared root canal wall, apical seal, Dentin Bridge, and size and location of perforations is easy using this method. The pulsed Nd:YAG laser is used for these purposes.

APICOECTOMY, RETROGRADE ENDODONTIC APICAL CAVITY PREPARATION AND PERIAPICAL CURETTAGE BY LASER

CO_2 and Nd:YAG lasers have been investigated for apicoectomy, retrograde endodontic apical cavity preparation, and periapical curettage.

Recently Er,Cr:YSGG laser was found to be more suitable for the treatment of soft and hard tissues.

Apicoectomy, retrograde endodontic apical root end cavity preparation, and periapical curettage can be performed using this one laser device. Cases with continuing clinical symptoms, root canals with fractured instruments, and sinus tracts in which pus drainage cannot be stopped by the standard endodontic treatment are included among the indications for this treatment.

Researchers have been studying ways to solve these problems using lasers. A decrease in microleakage due to closure of exposed dentinal tubules after laser irradiation on the cut surface at the root end as observed by scanning electron microscopy at apicoectomy sites was confirmed in vitro.

Er: YAG and ErCr: YSGG lasers are recommended for this treatment, but the cutting ability of the hard tissue by Er:YAG laser appears to be inferior to that of the ErCr:YSGG laser. The laser parameters should be determined based on the size and length of the root apex that is to be cut.

ROOT CANAL FILLING USING GUTTA-PERCHA OR RESIN AND LASER

Gutta-percha is thought to be melted by laser heat energy.

Anic and Matsumoto, attempted to investigate whether it is possible to perform the root canal filling using sectioned gutta-percha segments and a pulsed Nd:YAG laser. This was shown to be possible by the vertical condensation method, but the technique required too much time. At present, this technique is not practical.

Although a method combining argon laser and light-curable resin is in the literature. Proper application of this method requires further research.

REMOVAL OF TEMPORARY CAVITY SEALING MATERIALS, ROOT CANAL SEALING MATERIALS, AND FRACTURED INSTRUMENTS IN ROOT CANALS

Several methods have been used to remove temporary cavity sealing materials, root canal sealing materials, and fractured instruments in root canals, but there are no ideal methods.

Lasers are soon to be applied for these purposes. According to experimental results, it was easy to remove temporary cavity sealing materials made of zinc oxide, eugenol, or gutta-percha by pulsed Nd:YAG, Er:YAG, and ErCr:YSGG lasers; root canal sealing material made of resin or gutta-percha by pulsed Nd:YAG and Er:YAG lasers; and fractured reamers or files in slightly curved and wide root canals.

In narrow curved root canals, however, there were many cases in which the laser tips perforated the root canal wall.

LASER TREATMENT OF PERIAPICAL LESIONS OF SINUS TRACT

Although sinus tracts almost always can be closed by standard endodontic treatment, a few cases require special treatment.

Laser techniques are in cases for which apicoectomy or periapical curettage cannot be performed or for which standard endodontic treatment due to the presence of a deep post in the root canal are indications for this treatment and also used to accelerate the wound healing.

This treatment may be performed to accelerate wound healing in combination with endodontic or surgical treatment. Pulsed Nd:YAG and CO_2 lasers are recommended for these treatments.

For the pulsed Nd:YAG laser, 2W and 20 pps are the recommended parameters and the fiber tip must be inserted into the tract and drawn slowly from the root apex to the exit through the sinus tract. This treatment generally is performed three or four times during one visit. When using the CO_2 laser, the exit of the drainage must be ablated as deeply as possible at 1 or 2 W and under air cooling or local anesthesia.

The aforementioned laser treatments are performed once or twice a week until the sinus tract disappears.

Other Applications for the Endodontic Treatment

A pulsed dye laser emitted at 504 nm was used for the removal of a calcified attached denticle (Rocca et al. 1994).

CO_2 and Nd:YAG lasers have been used for the attempted treatment of root fractures (Arakawa et al. 1996). However, regardless of the reapproximation technique, laser type, energy, and other parameters used,fusion of the fractured root halves was not achieved.

Lasers (Ar, CO_2, Nd:YAG lasers) have been used successfully to sterilize dental instruments (Adrian & Gross 1979, Hooks et al. 1980, Powell & Whisenant 1991).

Hence, it can be concluded that it is useful to use lasers for endodontic treatment, however, it is yet not possible to use it alone. With the applications of thinner, more flexible and durable laser fibers, laser applications in endodontics will increase.

SUGGESTED READING

1. Anic I, Matsumoto K. Dentinal heat transmission induced by a laser-softened gutta-percha obturation technique. Journal of Endodontics 1995;21:470-74.
2. Arakawa S, Cobb CM, Rapley JW, Killoy WJ, Spencer P. Treatment of root fracture by CO_2 and Nd: YAG lasers: an in vitro study. Journal of Endodontics 1996;22:662-67.
3. Bader G, Lejeune S. Prospective study of two retrograde endodontic apical preparations with and without the use of CO_2 laser. Endodontics and Dental Traumatology 1998;14:75-78.
4. Dederich DN, Zakariasen KL, Tulip J. An in-vitro quantitative analysis of changes in root canal wall dentin due to pulsed neodymium-yttrium-aluminum-garnet laser irradiation. Lasers in the Life Sciences 1988;2:39-51.
5. Featherstone JDB, Nelson DGA. Laser effects on dental hard tissues. Advanced Dental Research 1987;1:21-26.
6. Hardee MW, Miserendino LJ, Kos W, Walia H. Evaluation of the antibacterial effects of intracanal Nd: YAG laser irradiation. Journal of Endodontics 1994;20:377-80.
7. Khan MA, Khan MFR, Khan MW, Wakabayashi H, Matsumoto K. Effect of laser treatment on the root canal of human teeth. Endodontics and Dental Traumatology 1997;13:139-45.
8. Koba K, Kimura Y, Matsumoto K, Takeuchi T, Ikarugi T, Shimizu T. A histopathological study of the morphological changes at the apical seat and in the periapical region after irradiation with a pulsed Nd: YAG laser. International Endodontic Journal 1998;31:415-20.
9. Levy G. Cleaning and shaping the root canal with a Nd: YAG laser beam: a comparative study. Journal of Endodontics 1992;18:123-27.
10. McKinley IB, Ludlow MO. Hazards of laser smoke during endodontic therapy. Journal of Endodontics 1994;20: 558-59.
11. Midda M, Renton-Harper P. Lasers in dentistry. British Dental Journal 1991;168:343-46.
12. Moritz A, Schoop U, Goharkhay K, Sperr W. The CO2 laser as an aid in direct pulp capping. Journal of Endodontics 1998;24:248-51.
13. Moshonov J, Orstavik D, Yamauchi S, Pettiette M, Trope M. Nd: YAG laser irradiation in root canal disinfection. Endodontics and Dental Traumatology 1995;11:220-24.
14. Paghdiwala AF. Root resection of endodontically treated teeth by erbium: YAG laser radiation. Journal of Endodontics 1993;19:91-94.
15. Potts TV, Petrou A. Laser photopolymerization of dental materials with potential endodontic applications. Journal of Endodontics 1990;16:265-68.
16. Stabholz A, Khayat A, Ravanshad SH, McCarthy DW, Neev J, Torabinejad M. Effects of Nd: YAG laser on apical seal of teeth after apicoectomy and retrofill. Journal of Endodontics 1992;18:371-75.
17. Takeda FH, Harashima T, Kimura Y, Matsumoto K. Efficacy of Er: YAG laser irradiation in removing debris and smear layer on root canal walls. Journal of Endodontics 1998;24:548-51.
18. Takeda FH, Harashima T, Kimura Y, Matsumoto K. A comparative study of the removal of smear layer by three endodontic irrigants and two types of laser. International Endodontic Journal 1999;32:32-39.
19. Wigdor H, Abt E, Ashrafi S, Walsh JT. The effect of lasers on dental hard tissues. Journal of American Dental Association 1993;124:65-70.
20. Zhang C, Kimura Y, Matsumoto K, Harashima T, Zhou H. Effects of pulsed Nd: YAG laser irradiation on root canal wall dentin with different laser initiators. Journal of Endodontics 1998;24:352-55.

23 Endodontic Implants

These implants are mainly responsible to stabilize the teeth where alveolar support is lost due to periodontal or endodontic problems. The function of an endodontic implant is to increase the root anchorage in the bone by the extension of the artificial material beyond the limit of the alveolar socket within the limits of the alveolar bone.

Indications

A. Periodontally involved teeth (Figs 23.1 and 23.2).
B. Transverse root fractures.
C. Unfavorable crown root ratio due to resorption.
D. Pathological/traumatic injuries.
E. Endodontically treated teeth with short anatomical roots.

Case Selection

1. Teeth with straight canals without considerable root curvature.
2. Cases of abnormal calcifications in the canals should be avoided.
3. Minimum sufficient height of alveolar bone should be present for the placement of implant.
4. Severe systemic disease may contraindicate implant placement

Causes for the Failure of Endodontic Implants

1. Improper apical seal at the junction of apex and the implant.
2. Extrusion of the root canal sealer

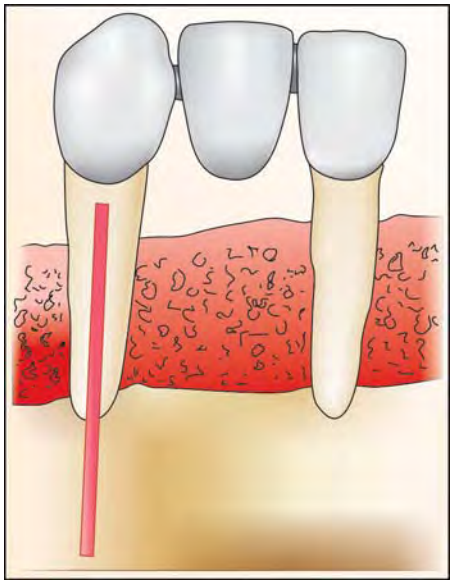


Fig. 23.1: Periodontally involved teeth (Generalized bone loss)

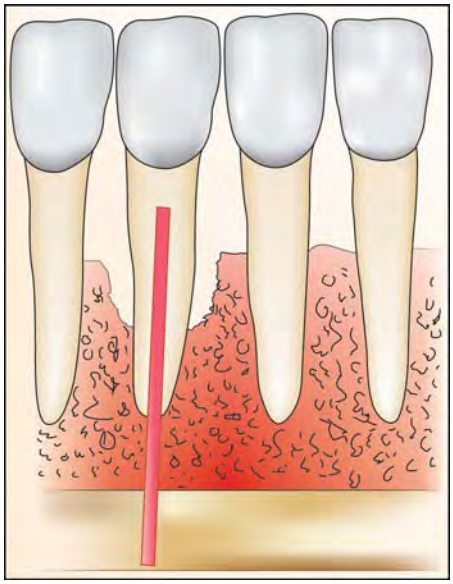


Fig. 23.2: Periodontally involved tooth (Isolated bone loss)

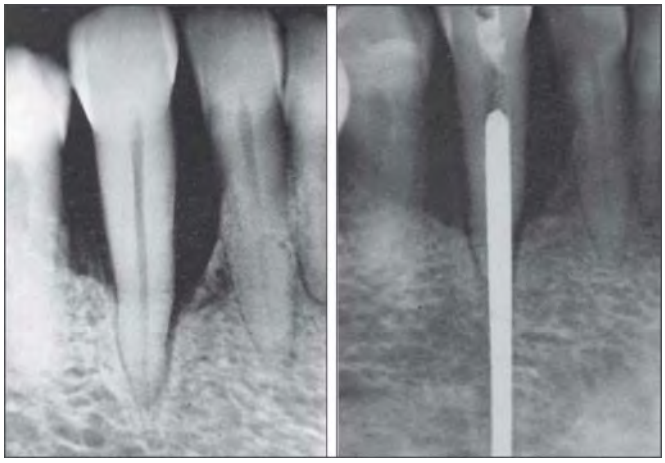


Fig. 23.3: Placement of endodontic implant

3. Functional incompatibility of jaws leading to the involvement of vital anatomic structures.

MATERIALS USED FOR ENDODONTICS IMPLANTS

1. Chrome cobalt alloys
2. Titanium

These implant surfaces may be coated with coating such as hydroxyapatite and plasma titanium spray.

Instruments Used

1. Extra long reamers (40 mm in length. No 70-140).
2. Special intraosseous drill.
3. Implants of size between No 70-140.

Procedure (Fig. 23.3)

- Under local anesthesia and rubber dam isolation, access preparation and vital pulp extirpation is carried out.
- 2-3 mm is added to determined working length so that the instrument perforates the apex with a minimal preparation size of No. 60.
- Intraosseous preparation is initiated using 40 mm reamers with the numbers smaller than the enlarged size.
- Bone is reamed approximately 10 mm beyond the apex with sequentially increased sizes so that a relatively round apical preparation is obtained.
- In cases of dense bone, extra long cylindrical drills may be employed to achieve the same.
- The intra-canal and extra-canal preparations should be enlarged till at least no 70, or until the apex is reamed round.
- In cases of hemorrhage canal is irrigated with local hemostatics.
- Canal is dried and sterile implant is carried using a heavy beaked hemostat and is tested for fit.
- If the implant is fitting to the working length and if the tugback is felt, implant is removed and cut at the apical tip by 1 mm in order to prevent butting against the bone.
- Incisal edge is marked over the implant using a carborundum disk. Canal is irrigated and dried without disturbing the apical blood clot.
- Cementation should be delayed until the blood clot has formed.
- The implant must be separated using a carborundum disk at a point below gingival level or even lower level if post placement is planned.
- Cement is applied to only the portion of the implant within the confines of the canal.
- A plugger with a stopper at the level 1mm more than the implant size is used to seat the inplant to final position and confirmed with a radiograph. Gutta-percha is used to seal the implant. The coronal restoration is done with a composite material.

SUGGESTED READING

1. Arens DE. An alternative treatment for the severely resorped maxillary lateral incisor: a sequela of ectopic eruption. J Endod. 1995;21(2):95-100.
2. E Thirty-months' clinical evaluation of vitallium endodontic endosseous implants. Egypt Dent J 1987; 33(2):97-107. No abstract available.
3. Larsen RM, Patten JR, Wayman BE. Endodontic endosseous implants: case reports and update of material. J Endod 1989;15(10):496-500.
4. Seltzer S, Green DB, De la Guardia R, Maggio J, Barnett A. Vitallium endodontic implants: a scanning electron microscope, electron microprobe, and histologic study. Oral Surg Oral Med Oral Pathol 1973;35(6):828-60.
5. Wayman WH, Mullaney TP.A comparative study of apical leakage with endodontic implant stabilizers. : J Endod 1975;1(8):270-3. Links
6. Zmener O. [Corrosion and biocompatibility of intraosseous endodontic vitallium implants in humans: report of 2 cases using scanning electron microscopy, electronic microprobe, and routine histological procedures] Rev Esp Endodoncia 1988;6(2):49-58. Spanish. No abstract available.

Pulpal regeneration after tooth injury is difficult to accomplish. This is the reason why infected pulp requires root canal therapy or tooth extraction. Tissue engineering aims at the regeneration of affected or lost pulp tissue using stem cell therapy.

Regenerative endodontic procedures can be defined as biologically based procedures designed to replace damaged structures, including dentin and root structures, as well as cells of the pulp-dentin complex.

The dental pulp contains progenitor/stem cells, which can proliferate and differentiate into dentin-forming odontoblasts (Nakashima et al, 1994; Gronthos et al, 2000, 2002). Following physiological stimulation or injury, such as caries and operative procedures, stem cells in pulp may be mobilized to proliferate and differentiate into odontoblasts by morphogens released from the surrounding dentin matrix.

Tissue engineering with the triad of dental pulp progenitor/stem cells, morphogens, and scaffolds may provide a useful alternative method for pulp-capping and root canal treatment.

However, the technique for manipulation of the growth of the isolated pulp progenitor/stem cells and induction of three-dimensional tissue formation invitro needs to be developed.

STEM CELLS (FIG. 24.1)

Stem cells are primal undifferentiated cells that retain the ability to divide and differentiate into other cell types. Stem cells differ from other kinds of cells in the body as all stem cells regardless of their source have

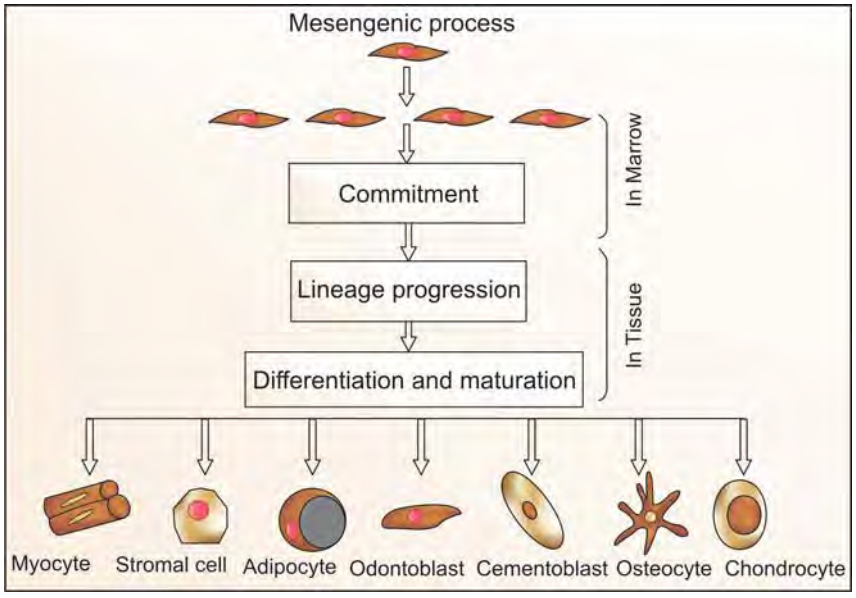


Fig. 24.1: Life cycle of stem cells

three general properties: they are capable of dividing and renewing themselves for long periods; they are unspecialized; and they can give rise to specialized cell types.

There are two types of stem cells:

1. *Embryonic (Fetal) stem cells*, as their name suggests, they are derived from embryos. Specifically, from embryos that develop from eggs that have been fertilized in vitro, in an in-vitro fertilization clinic and then donated for research purposes with informed consent of the donors. They are not derived from eggs fertilized in a woman's body.
2. *Adult (Postnatal) stem cell* is an undifferentiated cell found among differentiated cells in a tissue or organ, can renew itself, and can differentiate to yield the major specialized cell types of the tissue or organ. The primary roles of adult stem cells in a living organism are to maintain and repair the tissue in which they are found.

Functions of Adult Stem Cell

a. They exist as undifferentiated cells and maintain this phenotype by the environment and/or the adjacent cell populations until they are exposed to and respond to the appropriate signals.
b. They have an ability to self-replicate for prolonged periods.
c. They maintain their multiple differentiation potential throughout the life of the organism.

According to their source, stem cells can be categorized as autologous, allogenic or xenogenic, while according to their plasticity, stem cells can be totipotent, pluripotent and multipotent.

GOALS OF STEM CELL THERAPY IN TISSUE ENGINEERING

- Proliferate extensively and generate sufficient quantities of tissue.
- Differentiate into the desired cell types.
- Survive in the recipient after transplant.
- Integrate into the surrounding tissue after transplant.
- Function appropriately for the duration of the recipient's life.
- Avoid harming the recipient in any way.

Source of Pulp Stem Cells

The source of odontoblastoid cells that repair dentinal bridges has proved to be controversial. Initially, the replacement of irreversibly injured odontoblasts by predetermined odontoblastoid cells that do not replicate DNA after induction was suggested. Researchers proposed that the cells within the subodontoblast cell rich layer of Hohl adjacent to odontoblasts differentiate into odontoblastoids. The purpose of these cells seem to be limited to an odontoblast supporting role, as the survival of these cells is linked to the survival of the odontoblasts, and no proliferative or regenerative activity was observed.

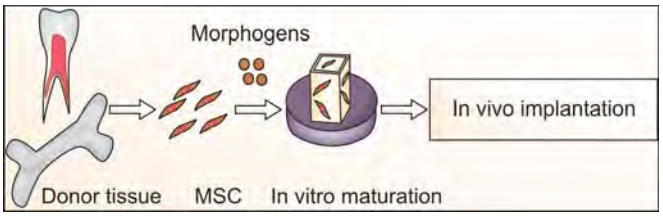


Fig. 24.2: Stem cell therapy

Stem Cell Therapy (Fig. 24.2)

Stem cell therapy is one of the most promising area s of tissue engineering because the transplantation of the materials that contain pulp stem cells grown in the laboratory provides an an inductive means to regenerate new tooth tissues. The transplantation of odontoblastoid stem cells into teeth to accomplish regeneration removes the problem of delivering growth factors and genes into host target cells and waiting for the target cells to differentiate. Recent studies focus on evaluating the use of human odontoblastoid stem cells transplantation for regeneration of oral tissues in conjunction with in vitro tissue engineering to produce regenerative biomimetic materials.

Scaffold (Fig. 24.3)

Scaffold provides a three-dimensional micro environment for cell growth and differentiation, promoting cell adhesion, and migration (Fig. 24.4). The

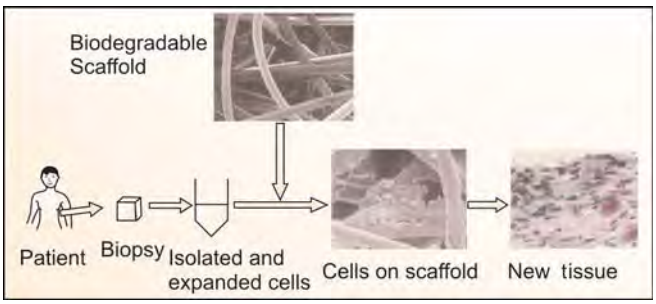


Fig. 24.3: Scaffold

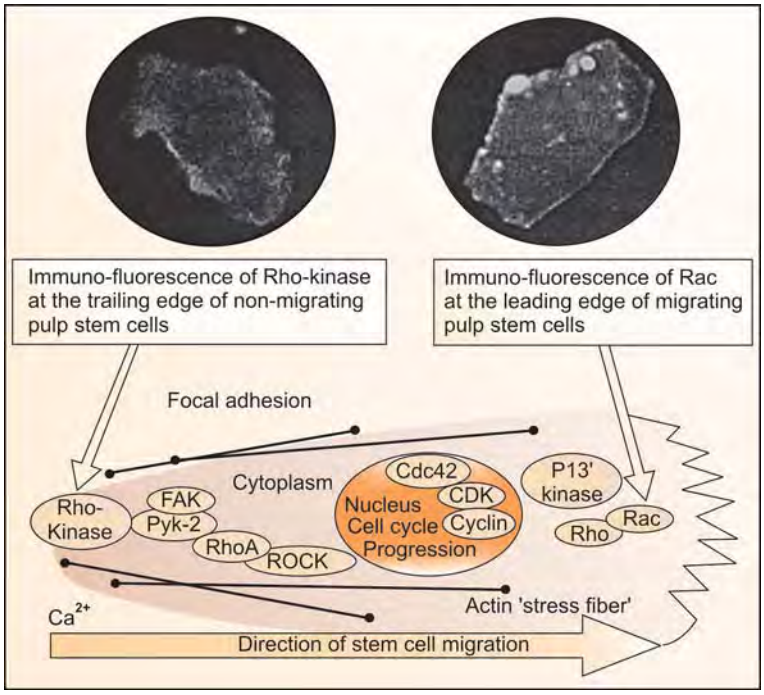


Fig. 24.4: The molecular regulation of pulpal stem cell migration. The migration of dental pulp stem cells seems to be controlled by a balance in the Rac/Rho-kinase activation. When Rac is activated, the cell migrates forward. When Rho-kinase is activated, the cell remains fixed in position. The signaling pathways of Rac/Rho-kinase are shown here

scaffold acts as a carrier for morphogen cells in cell therapy. Scaffold should have transport of nutrients, oxygen, and waste across them. Scaffold should be slowly degraded and replaced by regenerative tissue, retaining the feature of the final tissue structure. They should have biocompatibility, nontoxicity, and good physical properties.

Scaffold materials can be:

1. Natural
   a. Collagen
   b. Glycosaminoglycans
2. Synthetic
   a. *Synthetic polymers*
      - Poly (lactic acid) (PLA)
      - Poly (glycolic acid) (PGA)
      - Poly (lactic-co-glycolic acid) (PLGA).
   b. *Synthetic hydrogels*
      - Poly (ethylene glycol) (PEG) based polymers.
   c. *Synthetic hydrogels modified with cell surface adhesion peptides*
      - Arginine.
      - Glycine.
      - Asparticacid (RGD).
   d. *Inorganic compounds*
      - Hydroxyapatite
      - Calcium phosphate.

Morphogens

A major focus of contemporary studies in developmental biology has been to delineate the biological cues that drive stem cell proliferation and differentiation. Four signaling protein families that govern patterning and morphogenesis have been identified:

- Fibroblast growth factors,
- Hedgehog proteins,
- Bone morphogenetic proteins,
- Wingless- and int-related proteins (Wnts).

Proteins from each of these families are now being evaluated for their utility for stem cell based engineering of craniofacial defects. Recently, these applications have been extended to treat the diseases of endodontic origin.

Naturally derived collagen or synthetic materials such as polyglycolic acid (PGA) are used as a scaffold for attachment and guidance of cells. The pulp derived fibroblasts adhering to the PGA fibers can proliferate and form a new tissue similar to that of native pulp

The synthetic matrices, however, must undergo degradation simultaneously with the new tissue formation by the cultured cells.

Bone morphogenetic proteins (BMPs) have been implicated in tooth development, and the expression of BMP2 is increased during the terminal differentiation of odontoblasts. Beads soaked in human recombinant BMP2 induce the mRNA expression of Dspp, the differentiation marker of odontoblasts after implantation onto dental papilla in organ culture. BMP2 also induces a large amount of reparative dentin on the amputated pulp in vivo (Nakashima, 1994a). It has been suggested that BMP2 may regulate the differentiation of pulp cells into odontoblastic lineage and stimulate reparative dentin formation (Nakashima and Reddi, 2003).

Vascular Regeneration

Vascularization is very important in tissue repair and regeneration. Vascular endothelial growth factor (VEGF) is the regulator of angiogenesis and is known to increase vascular permeability. VEGF induces chemotaxis, proliferation and differentiation of human dental pulp cells. In addition human dentin matrix contains VEGF.The presence of VEGF in dentin and response of dental pulp cells to VEGF raises the possibility of the presence of endothelial progenitor cells in dental pulp alongside progenitors for odontoblasts and neuronal cells. Along with endothelial progenitor cells in vascularization during tissue regeneration, it is likely VEGF and vascular endothelial cells are critical for dentin regeneration.

Steps and obstacles in regenerative endodontics:

A. Disinfection and shaping of canals
B. Creation of replacement pulp-dentin tissue
C. Delivery of replacement pulp-dentin tissue
D. Dental restorative materials
E. Measuring appropriate clinical outcomes

Potential technologies for regenerative endodontics (creation of replacement pulp-dentin tissue):

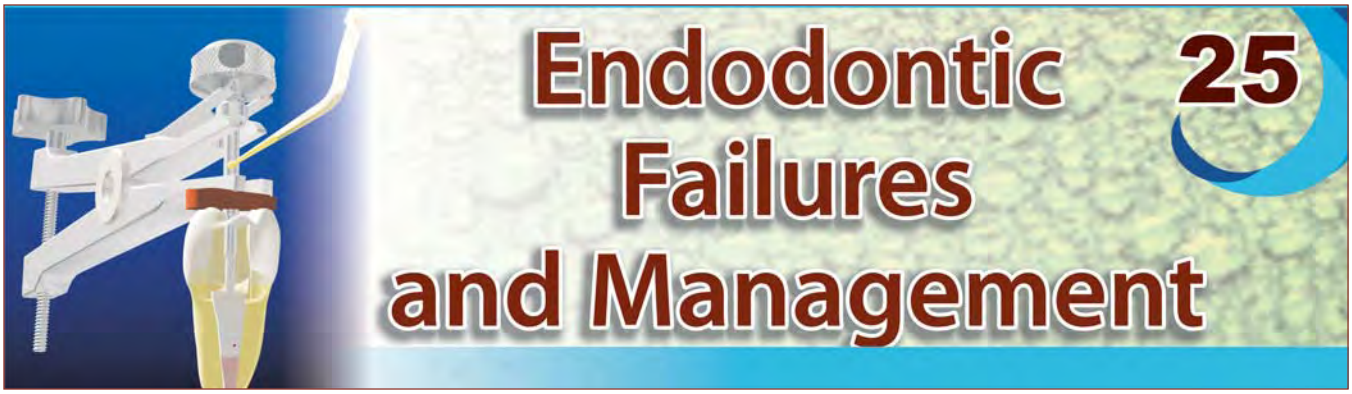
1. Root canal revascularization via blood clotting
2. Postnatal stem cell therapy
3. Pulp implantation
4. Scaffold implantation
5. Injectable scaffold delivery
6. Three-dimensional cell printing
7. Gene delivery

Future Directions

The last decade has proved to be an exciting time for pulp biology and has led to rapid advances in our knowledge of repair in this tissue. At the start of a new millennium, the use of biological molecules for the development of novel restorative treatment modalities in clinical dentistry is in sight. These approaches have potential applications in unexposed cavity preparations for protection of the pulp from harmful effects of dental materials by increasing the residual dentin thickness through reactionary dentinogenesis, as well as in exposed pulp situations for restoration of the structural integrity of the dentin wall by reparative dentinogenesis. In the severely compromised pulp, it may even be possible to use biological approaches in endodontic therapy to seal the root canal.

SUGGESTED READING

1. Anthony J. (Tony. Smith Tooth Tissue Engineering and Regeneration-a Translational Vision! J Dent Res 2004;83(7):517.
2. Bruce J Baum, David J. Mooney. The impact of tissue engineering on dentistry JADA, 2000;131.
3. D Rekow. Informatics challenges in tissue engineering and biomaterials Adv Dent Res 2003;17:49-54.
4. K Iohara, M Nakashima, M Ito M Ishikawa, A Nakasima, A Akamine. Dentin Regeneration by Dental Pulp Stem Cell Therapy with Recombinant Human Bone Morphogenetic Protein 2J Dent Res 2004;83(8).
5. Misako Nakashima, A Hari Reddi. The application of bone morphogenic proteins to dental tissue engineering.Nature biotechnology, 2003;21(9)1025-32.
6. Misako Nakashima, Akifumi Akamine. The Application of Tissue Engineering to Regeneration of Pulp and Dentin in Endodontics, JOE - 2005;31(10).
7. Michel Goldberg, Anthony J. Smith Cells and extracellular matrices of dentin and pulp: a biological basis for repair and tissue engineering Crit Rev Oral Biol Med 2004;15(1):13-27.
8. MT Duailibi, SE Duailibi, CS Young2, JD Bartlett2, JP Vacanti, PC Yelick. Bioengineered Teeth from Cultured Rat Tooth Bud Cells J Dent Res 2004;83(7):523-28.
9. Risbud MV, Shapiro IM. Stem cells in craniofacial and dental tissue engineering Orthod Craniofacial Res 2005;8:54-59.
10. Y Nakamura, L Hamarstrom, K.matsumoto, SP lingstadass. The induction of reparative dentin by enamel proteins. Intrnational Endodontic Journal. 35:407-412:2



The success rate of endodontics therapy is nearly 90-95 percent. Still 5 percent cases are deemed as failures. In the global scenario, this 5 percent will account to a very large number when assessed for a period of one year.

The causes for endodontic failure are mainly divided into:

1. Improper case selection
2. Procedural errors during Access opening
3. Procedural errors during Biomechanical preparation
4. Procedural errors during Obturation
5. Miscellaneous

CASE SELECTION

Case selection is a very important step in the endodontic therapy.

Factors:

a. Involvement of coronal tooth structure by caries or trauma
b. Improper occlusion
c. Oral hygiene
d. Length of the remaining clinical crown
e. Previous restorations and health of periodontal ligament:
   a. *Involvement of coronal tooth structure by caries or trauma (Fig. 25.1):* The extent of caries involvement and its extension to the root surface and sometimes floor or furcation of the pulp chamber has to be evaluated clinically and radiographically and such cases have to be assessed for longevity of final restoration.
   b. *Improper occlusion (Fig. 25.2):* Occlusion should always be verified before treatment. Improper occlusion may be due to the rotation, tilting, drifting or supra eruption of the tooth from the opposite arch.
   c. *Oral hygiene:* Good oral hygiene is very necessary for success of endodontic therapy as poor oral hygiene contributes to the growth of microorganisms, especially resistant strains, which may be difficult to eradicate by the use of routinely used irrigating solutions. The patients should be advised thorough oral prophylaxis followed by oral hygiene instructions, i.e. brushing, flossing and use of mouth rinses.

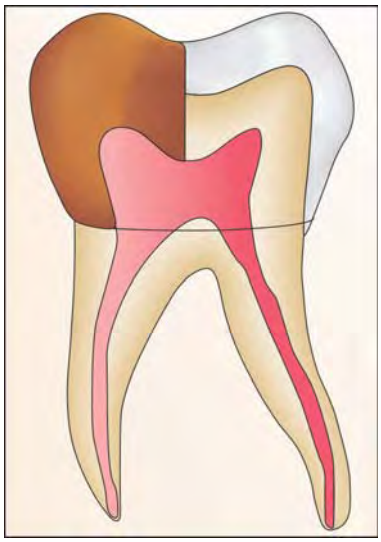
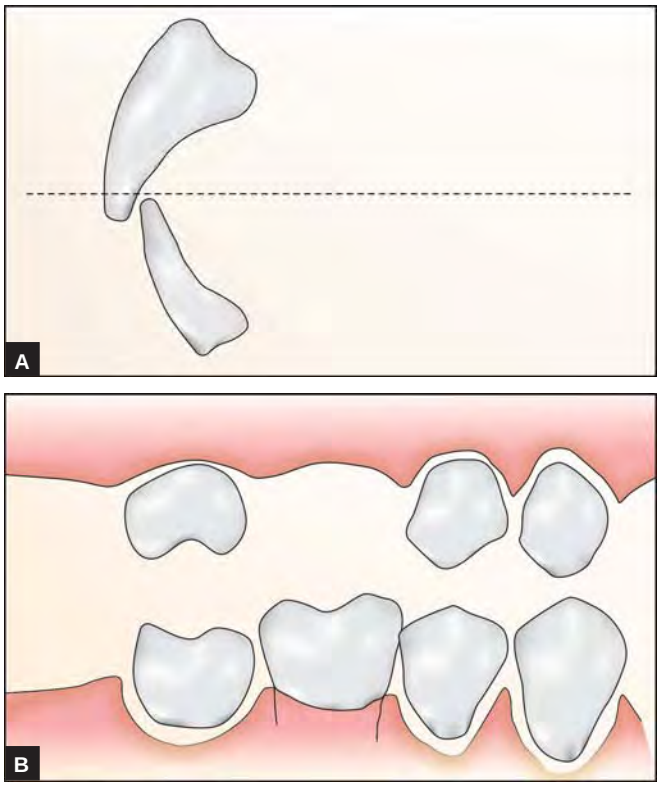


Fig. 25.1: Caries involving extensive tooth structure



Figs 25.2A and B: Occlusion

d. *Length of the clinical crown (Fig. 25.3):* According to clinical studies there should be at least 2 mm of remaining coronal tooth structures otherwise the prognosis of endodontic therapy would be compromised. The clinician should have a clear idea of final restoration and its durability before initiating endodontic therapy. After endodontic treatment the final restoration should have a durability of at least 10 to 20 years. If the length of the clinical crown is less it can be increased by crown lengthening procedures such as gingivectomy, orthodontic extrusion, etc.

e. *Previous restorations (Fig. 25.4):* The tooth undergoing endodontic therapy should be carefully assessed for the integrity of old restorations. Defective restoration should be removed. Secondary caries should be excavated and the restorations should be replaced using GIC or composite prior to the endodontic therapy.

f. *Health of periodontal ligament (Fig. 25.5):* This is a critical area in the evaluation of endodontic therapy. The investing tissues of the teeth such as gingiva, periodontium and alveolar bone have

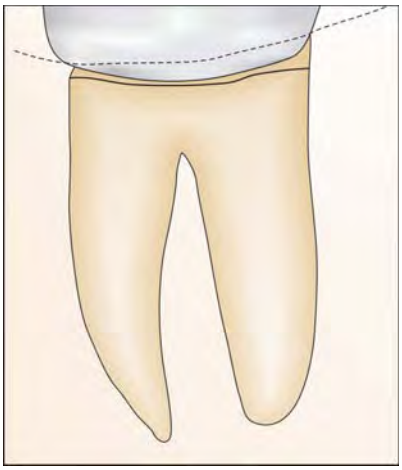


Fig. 25.3: Clinical crown height

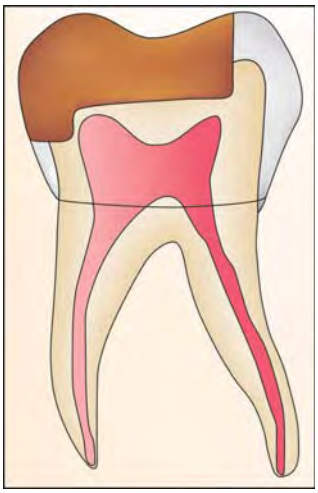


Fig. 25.4: Previous restoration

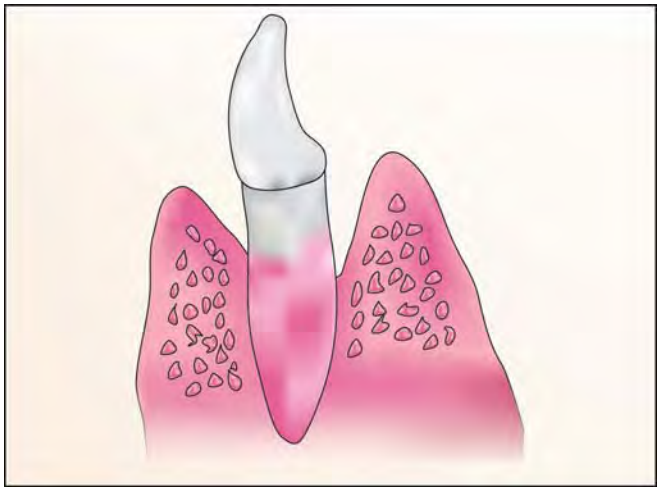


Fig. 25.5: Periodontal ligament and bone loss radiographic findings

to be assessed for health. Clinical assessment of mobility of the tooth should be done. Periodontal examination and careful radiographic assessment of bone loss is essential. Decision should to be taken by an interdisciplinary approach in consultation with periodontists.

Radiographs are very important in the assessment of endodontic failures. Improper radiographs, errors in angulations, improper exposure time, and improper development contribute to poorly diagnostic radiographs which is difficult to read and interpret. The radiograph reveals root canal morphology. Configuration of the pulp chamber and the root canals, presence or absence of calcification in pulp chamber or root canals. This information is very useful and plays an important role in endodontic therapy.

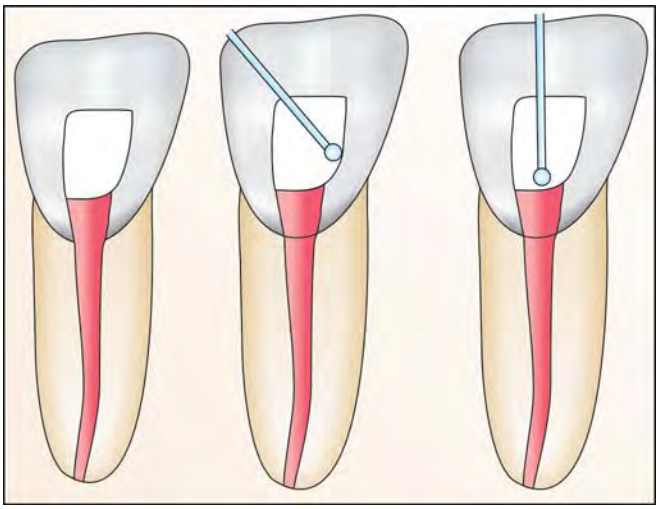


Fig. 25.6: Direction of the bur

Access Opening

Direction of the bur during access opening plays an important role. In case of anterior teeth, it should be parallel to the long axis of the tooth (Fig. 25.6). In posteriors, it should be directed towards locations of the larger canals. It should be done with minimal removal of tooth structure. Anterior tooth perforation occurs most commonly at CEJ.

In posterior teeth when perforation occurs at the furcation area, there will be profuse bleeding. Control of the hemorrhage should be done with cotton pellets placed in the pulp chamber with pressure or hydrogen peroxide in a cotton pellet under pressure. Wait for 2-5 min till the bleeding stops. Locate the bleeding points carefully and use a biocompatible material to seal the perforation. Such materials include MTA (Fig. 25.7), calcium hydroxide and zinc oxide eugenol and its modifications. Use of zinc oxide eugenol for perforation repair is controversial as many studied have proved that it irritates the tissues.

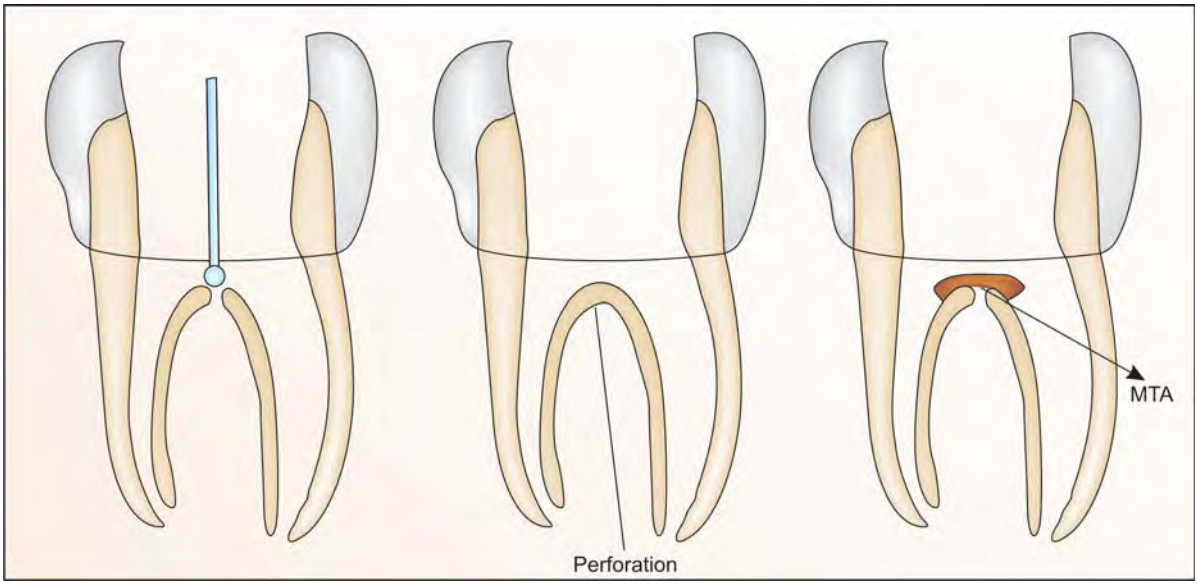


Fig. 25.7: Perforation repair

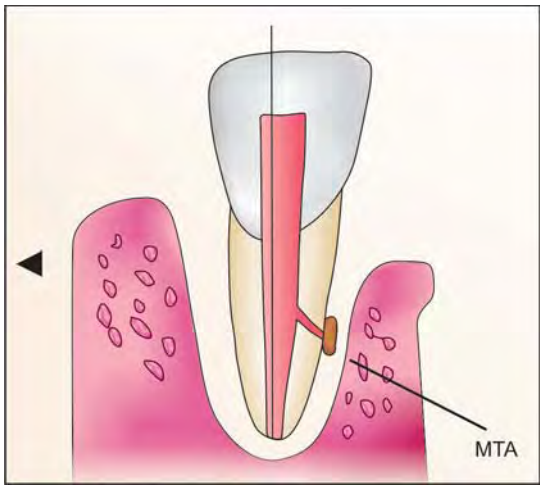


Fig. 25.8: MTA perforation repair

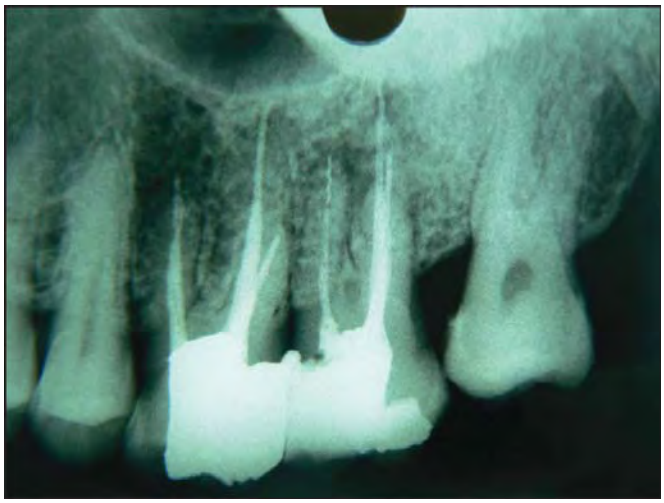


Fig. 25.9: Radiograph showing broken instrument in the mesiobuccal root of maxillary second molar

Biomechanical Preparation

During biomechanical preparation perforation of the root canal may occur. The level of perforation may be

a. Mid root
b. Apical third

If the peroration occurs in the canal, locate the perforation area by using an apex locator. Surgical intervention is often required. Reflect the flap, locate the perforation area and follow by adequate cleaning. Place the instrument in the canal and the restorative procedure should be undertaken. Previously amalgam was the material of choice. Now with the advent of advanced newer materials it is rarely being used.

Calcium hydroxide can be used as sub-base and the restoration can be completed using either glass ionomer cement, IRM, MTA, etc. (Fig. 25.8).

If the clinician is unable to locate the canals, loupes and microscopes can be used to aid in magnification.

Broken Instrument (Fig. 25.9)

One of the important and most commonly encountered clinical mishaps is instrument breakage. It is better to prevent instrument breakage rather than to attempt its removal after breakage. The success of removal of broken instrument depends upon the location, direction of the instrument and type of the instrument (Figs 25.10 to 25.18).

Considerations in Assessing Fractured Instruments

- When the instrument broke - at the beginning or end of preparation

Fig. 25.10: Broken instrument in the middle third

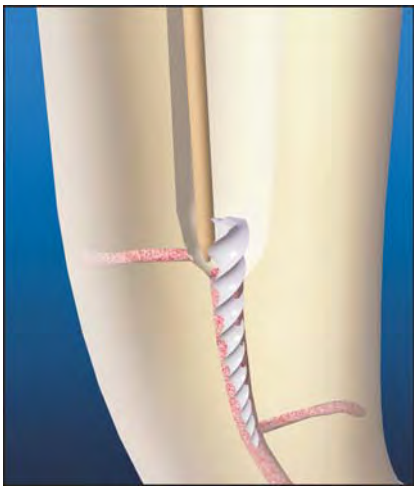


Fig. 25.11: Removal using ultrasonic tips

Fig. 25.12: Broken instrument at apical third

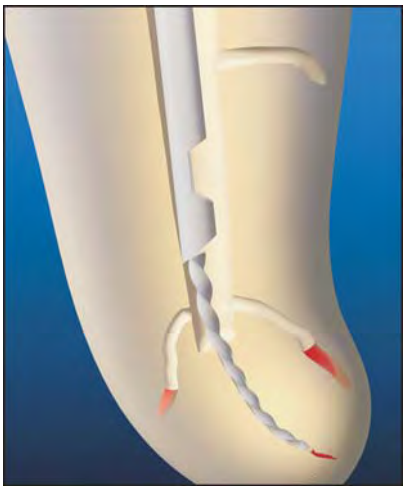


Fig. 25.13: Instrument removal kit

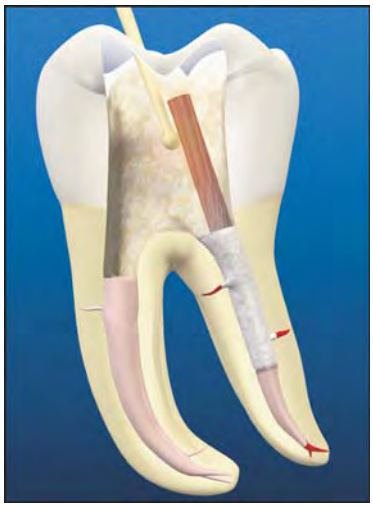


Fig. 25.14: Vibration applied using ultrasonic tips

Fig. 25.15: Broken instrument taken out of the canal

Fig. 25.16: Improper positioned post

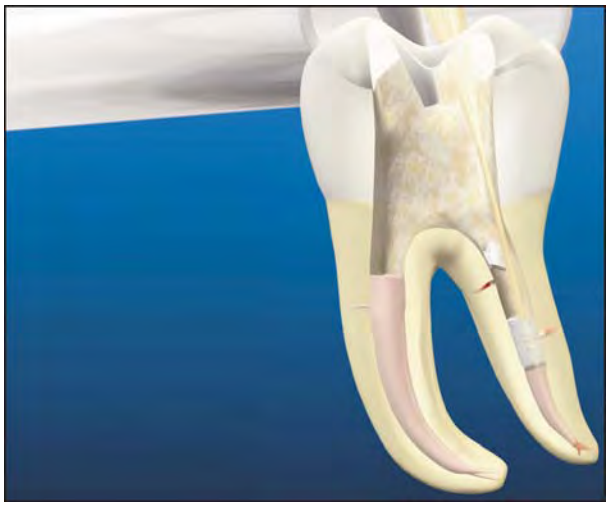


Fig. 25.17: Removal of the post

Fig. 25.18: Removal of the cement

- Multiple radiographic angles
- Width and length of the fragment
- Type of metal - stainless steel or nickel titanium
- Location of instrument - coronal, middle or apical third
- Anatomical cross-section of the canal - round or oval
- Position of any curvature/recurvature, and portion of fragment within this curvature
- Presence or absence of apical periodontitis.

Precautions to Minimize Instrument Fracture

1. Considering files as disposable items, discarding damaged instruments during treatment.
2. Not forcing instruments.
3. Using instruments in the correct sequence, alternating sizes and tapers as appropriate.
4. Not rotating stainless steel instruments more than a quarter turn clockwise.
5. Confirming a glide path to size 20 with hand files prior to using rotary NiTi instruments.
6. Taking care with certain canal anatomy when using nickel titanium, e.g. canals that merge, divide or are dilacerated.
7. Ensuring straight line access before preparing the canals, thereby reducing stress on the instruments.

Fig. 25.19: Instrument removal system (IRS)

H-files: A space is made by working around the broken instrument and retrival is accomplished by twisting multiple files in clockwise rotation and subsequent removal.

Instrument Removal System (Dentsply) (Fig. 25.19)

IRS is a new instrument removal system which allows for the effective removal of canal obstruction, including separated instruments. The kit comprises of a microtube with a side opening used to 'trap' the obstruction, e.g. the separated instrument and a 'screw wedge' to secure the obstruction in the microtube which once secured is then removed along with the microtube.The product is available as a starter kit which comes with two microtube sizes, one designed for narrow canals and one designed for wide canals (diameter 0.6 mm and 0.8 mm). The IRS system is also available separately.

Roydent Endo-extractor

The Endo-extractor system is excellent for removal of separated files and silver points.

- The "Jacobs Chuck"-like device grabs the embedded article with equal force all the way around, requiring minimal pressure.
- Unique hollow trepan drill with an internal diameter of 0.80 mm.
- Stainless steel.
- Sterilizable with autoclave, Chemiclave or dry heat sterilization.
- Available in complete kit or individual sizes.

Ruddle's Instrument Removal System/Post Removal System

Masserann kit (Figs 25.20 and 25.21)

The Masserann kit consists of a number of trepans with diameters from 1.1 to 2.4 mm. The trepans are hollow tubes designed to cut a trough around the metal fragment. These trepans are designed to be used with an anticlockwise rotation. This will assist with the removal of any threaded materials which will have a conventional thread. The operator should be aware of this as a potential problem if attempting to remove a fractured Hand File of Greater Taper, which has a reverse thread. The trough usually has to be cut along at least half the length of the fragment before it is sufficiently loosened to allow its extraction. It is recommended that the trepan is operated by hand, using the special handle provided, and not placed in a handpiece. A feeler gauge from the kit is used to assess the size of the trepan required. EDTA paste will help to lubricate and soften the dentine. The kit also contains a Masserann extractor, which is placed over the end of the loosened fragment so that it may be gripped and removed. If the fragment is too large for the extractor, then a size smaller trepan may be forced over the end of the fragment, which is then gripped firmly enough to allow its withdrawal from the canal.

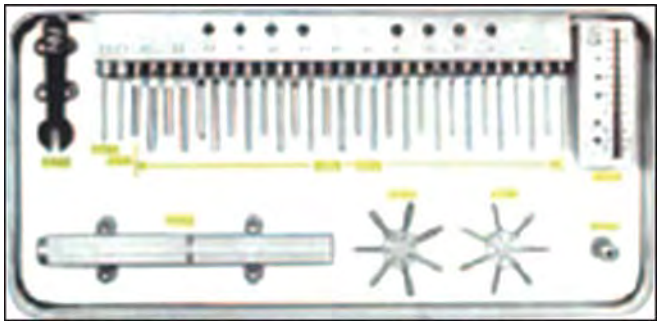


Fig. 25.20: Masserann kit

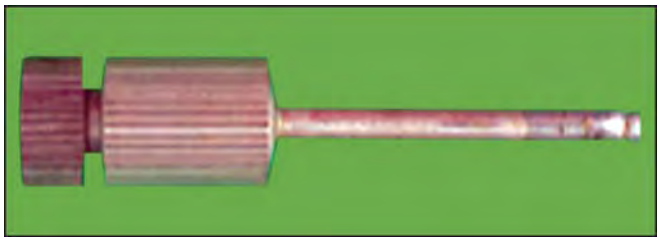


Fig. 25.21: Masserann extractor

If it is difficult to remove the broken instrument try to bypass it. Complete the biomechanical preparation followed by obturation.

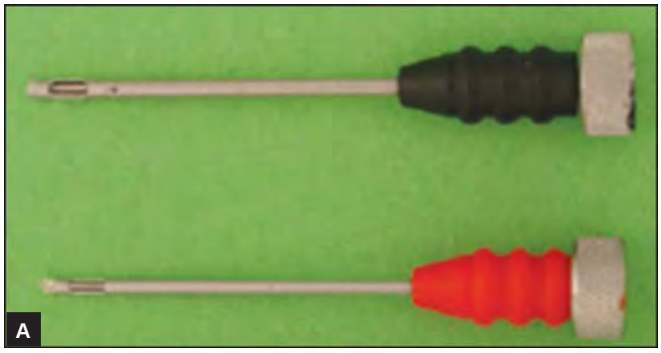
OTHER SYSTEMS: RUDDLE'S KIT (FIG. 25.22)

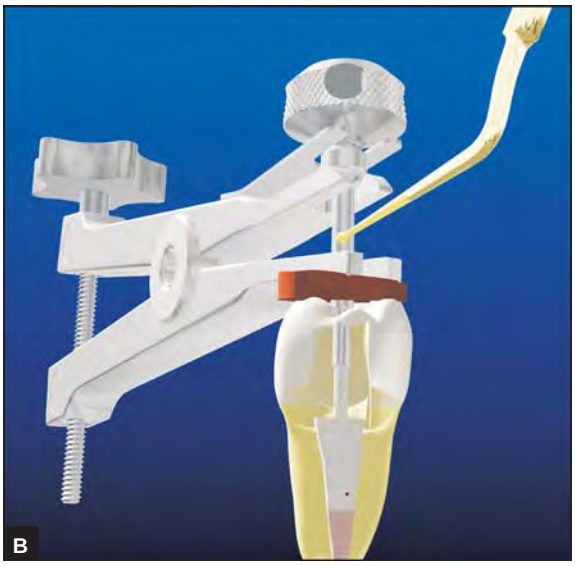
Ledge Formation

Ledge formation is a deviation from the original canal curvature without communication with the periodontal ligament, resulting in a procedural error also known as ledging.

Causes

1. Inadequate extension of the access cavity to allow adequate access to the apical part of the root canal.
2. Loss of control of the instrument during access opening from proximal surface.





Figs 25.22A and B: Ruddle's instrument/post removal kit

3. Incorrect assessment of the root canal direction.
4. Improper working length determination.
5. Forcing and driving the instrument into the canal.
6. Failure to precurve the stainless steel instrument that is too large for a curved canal.
7. Failing to use the instruments in sequential order.
8. Over-reaming the file at the working length.
9. Inadequate irrigation and/or lubrication during instrumentation
10. Excessive use of chelating agents.
11. Attempting to retrieve broken instruments.
12. Removing root filling materials during endodontic retreatment
13. Attempting to prepare calcified root canals.
14. Attempting to prepare blocked canals.

Management (Figs 25.23 to 25.25)

1. Negotiate the ledge with smaller instruments and bypass the ledge followed by obturation.
2. Use of Greater taper files can also be used to remove the ledge followed by obturation.
3. If negotiation is not possible, surgical management should be undertaken.

Elbow Formation (Fig. 25.26)

If more pressure is used on the lateral wall of the apex during biomechanical preparation, elbow will form.

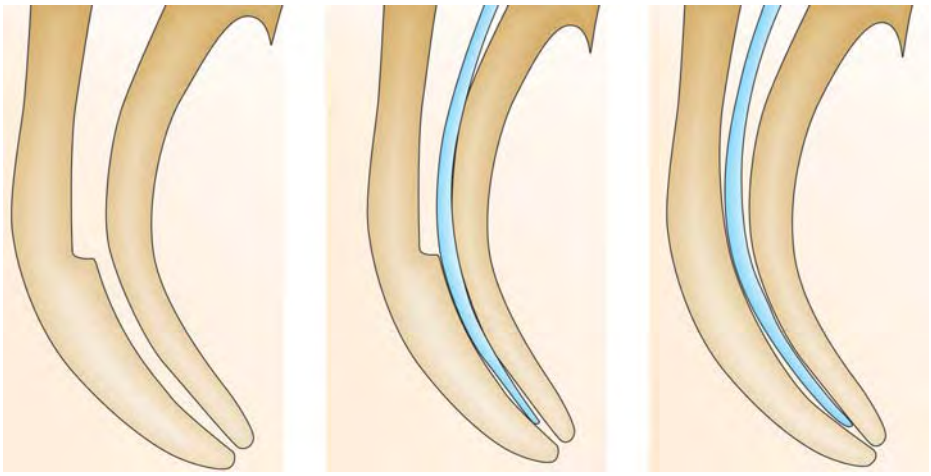


Fig. 25.23: Ledge formation, negotiation of ledge formation, ledge removal

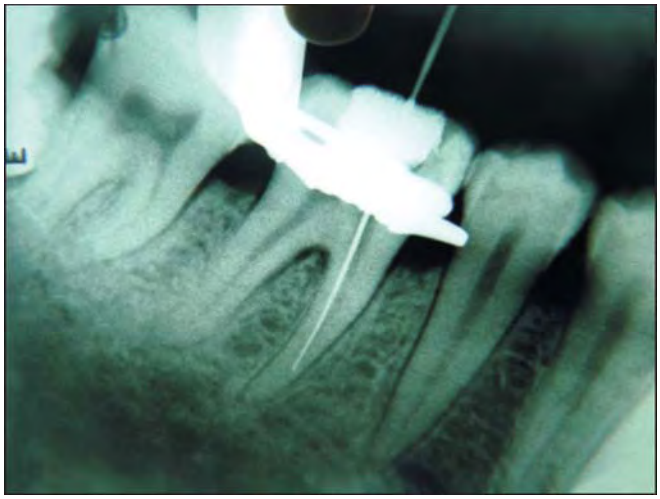


Fig. 25.24: Ledge formation

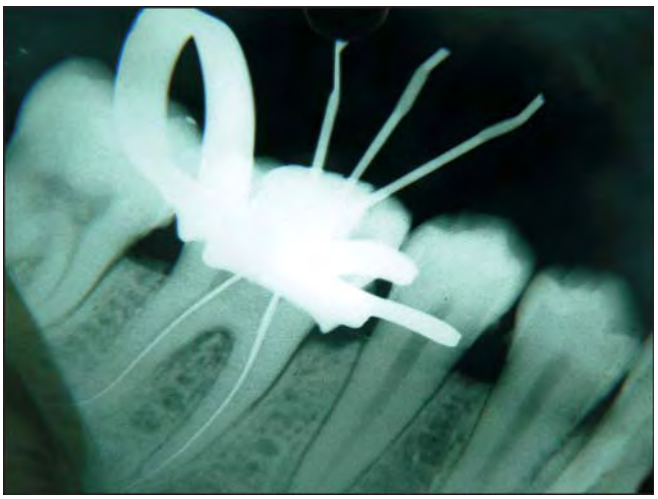


Fig. 25.25: Negotiation of ledge formation

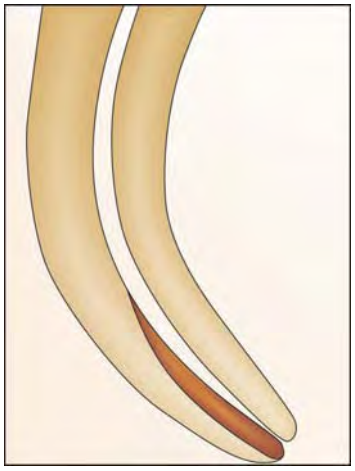


Fig. 25.26: Elbow

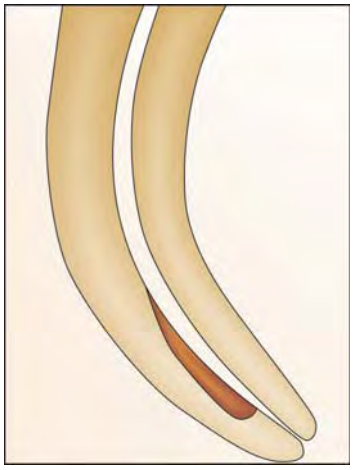


Fig. 25.27: Zipping

Zipping (Fig. 25.27)

Zipping is defined as the elliptical shape that may be formed in the apical foramen during the preparation of a curved canal when a file extends through the apical foramen and subsequently transports the outer canal wall. Misdirection of the root canal instrument away from the periapical opening results in zipping.

Prevention

- Precurve the instrument
- Use in proper sequence / recapitulation
- Prevent lateral perforation at apex
- Radiograph should be assessed with the instrument in places.

Improper Use of Irrigating Solutions

Irrigation should be used with maximum care to prevent damage to periapical tissues.

Precautions

1. Needle should be loose in the canal.
2. Needle should not be at the apex
3. Force should be less.

Improper Cleaning and Shaping of the Canals

In case of multiple canals, it is very common to leave some of the infected tissue in the canals.

- Ultrasonic instruments are best to remove any infected tissue at the isthmus and the canal. In the curved canal improper enlargement of orifice leads to removal of dentin at the outer portion enlarge with GG drills or Peeso reamer
- Use GG no- 1 up to the first curvature followed by sequential increase till no. 3 so that the canals can be straightened.
- If stainless steel instrument are used pre-curving is advised to follow curvature of the canal.
- NiTi instrument are safer in curved canals due to superelasticity and shape memory. However, cutting efficiency is less.

OBTURATION (FIGS 25.28A AND B)

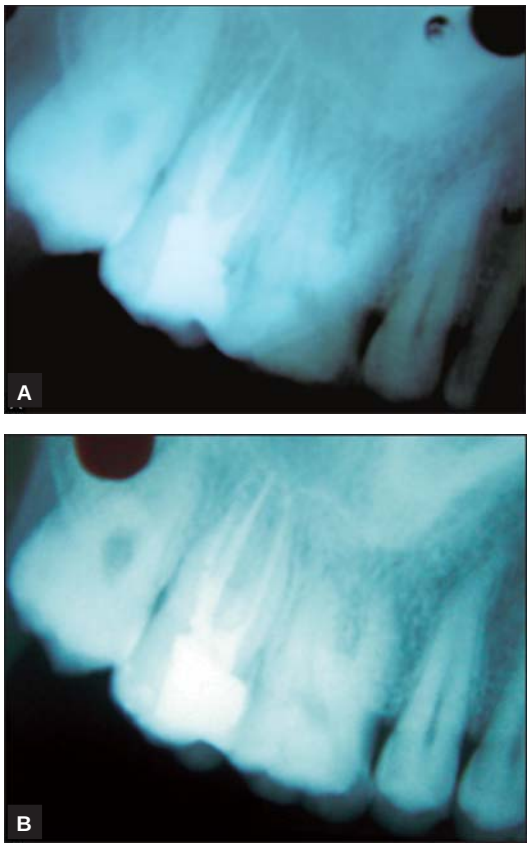
Removal of gutta-percha can be done by 3 methods.

Chemical Method

Solvents such as oil of eucalyptus, oil of turpentine and chloroform have been used to soften gutta-percha for removal, chloroform being the most efficient. However, chloroform is hazardous to use as this is toxic and potentially carcinogenic. Oil of turpentine is less toxic, but there is concern that solvents in general lead to a dimensional change in the gutta-percha, leading to increased microleakage. This together with the fact that it is difficult to control the depth of softening of the gutta-percha and potential leakage of the solvents into the periradicular tissues.

Thermal Removal

A heated instrument can be inserted into the gutta-percha to the desired length to soften and remove the gutta-percha. In narrow canals, a System B spreader



Figs 25.28A and B: (A) Over obturated maxillary second molar (B) Adequately obturated maxillary second molar

is ideal for removal of gutta-percha. From a pre-operative radiograph, a plugger should be chosen of the correct dimensions, that is likely to bind at the desired length and this position should be marked on the plugger with a rubber stop. The tip should be placed in the gutta-percha and with the heat applied, driven slowly to the desired length in about 2-3 seconds. The heat should be removed the plugger to cool for about 7-10 seconds, twisted and then removed with the gutta-percha. Some authors suggest that gutta-percha should be removed with heat techniques only and mechanical removal only used if heat is insufficient.

Mechanical Method

This is most commonly used technique. But, it is a technique that can result in damage to tooth tissue and periodontal apparatus. When using mechanical method care should be taken not to weaken the tooth or perforation. Recent studies have proved that combination of the heat and the mechanical method is superior. H-files are commonly used (Figs 25.29 and 25.30). Sometimes gates glidden drills and Peeso reamers are also used. Recently rotary instruments such as Profiles, Protaper retreatment files, K3 files and lasers are being used for gutta percha removal. Heat liberated during rotary removal may damage the periodontium.

Removal of Silver Points

Can be bypassed or removed depending on canal anatomy.

If the operator bends or leaves the excess of silver cone, it can be removed easily either by using Steiglitz forces, microsurgical forceps or Caufield elevator tips.

Ultrasonic vibrations can be applied to loosen the silver point from the sealer.

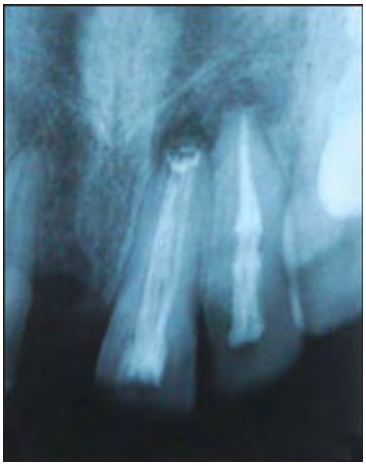


Fig. 25.29: Improper obturation

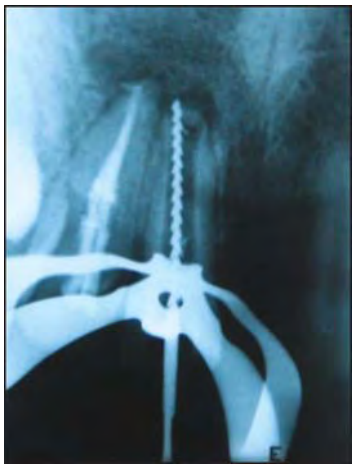


Fig. 25.30: Removal by H-file

A space is made by working around the point and retrieval is accomplished by twisting multiple H-files in clockwise rotation and subsequent removal.

Cancelier tubes or hypodermic needle can be used with superglue (cyanoacylate) and subsequent removal.

Removal of Pastes and Cements

Soft-setting pastes. Soft-setting pastes may be penetrated with files using crowndown method to remove the paste from the entire canal.

Hard-setting cements. Resin-type cements should be removed using solvents like tetrachlorethylene, xylene, eucalyptol, or eugenol. Once softened, the cement is managed like soft-setting pastes. If not, the cement is broken down with moderate ultrasonic vibration, using special pointed tips under light apical pressure to prevent perforation.

POST REMOVAL

Advent of dual cure resin cements led to increased bonding between post material and tooth structure.

Various post removal systems are:

1. Roto-Pro Bur
2. Thomas screw post removal kit
3. Gonon post removal system
4. Eggler's post removal system
5. Ruddle's post removal system

Roto-Pro Bur (Ellman International,Helwett,NY) (Fig. 25.31)-Available in four shapes. Six sided instrument with non cutting tip. Used in a high speed handpiece. When non-cutting flutes come in contact with the post, vibrations are created leading to subsequent loosening and removal of the post. When used in a high speed air driven handpiece, they will produce rotary ultrasonics of about 20,000 vibrations per second.

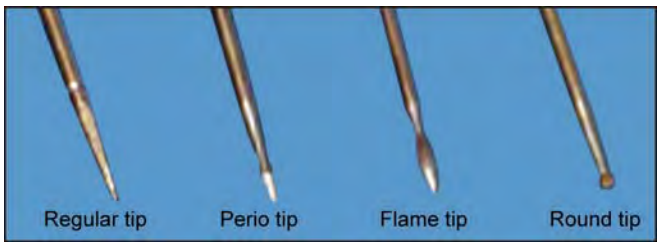


Fig. 25.31: Roto-Pro bur

Thomas Screw Post Removal Kit

This system is designed for active or screwed posts. It has trephine burs and extraction mandrels. The mandrels are reverse threaded to tap onto the screwed post in anti-clockwise manner.

Gonon Post Removal System (Gonon master post extractor) (Fig. 25.32)

This is an improved, stainless steel extractor in a kit, specially designed for removing whole or broken posts inside the root canal in three easy steps. The extractor may be used on posts made of steel, gold, and stainless steel.The kit contains four special counter-clockwise mandrels. The kit contains a Pointer drill, four trephine burs sized 1.15 mm to 1.60 mm, four tubular taps, four CCW taps, set of washers, and pliers with screw knob. Screw post removal is easy and successful with this system.

Eggler's Post Removal System

In Eggler system, the core must first be shaped so that its sides are parallel and capable of being gripped. The mesial and distal shoulders of the crown preparation must be cut to the same height so there is no torsional force. The post extractor is then placed over the post and the screw tightened onto the core; the feet are then lowered on to the shoulders of the preparation by turning the end knob. Several more turns will ease the post out of the post hole.

Fig. 25.32: Gonon kit

Ruddle's Post Removal System

In this system, a trephine is used to produce a parallel side in the post, which is then grasped in a matching sized thread cutting tap to a maximum depth of 3 mm. The post removal pliers are placed over a rubber cushion, and gently tightened. If removal is difficult, further ultrasonic energy may be applied. As with all such instruments, there is a danger of root fracture, and expertise should be gained in a technical laboratory before attempting these techniques in a clinical situation.

REMOVAL OF ESTHETIC POSTS

Various post removal burs for the esthetic post systems are:

1. Largo bur
2. Gyro tip (plasma coated silicon carbide)

It is difficult to remove ceramic and zirconia posts. Ceramic posts can be drilled with diamond with high risk of perforation, but Zirconia post is almost impossible to retrieve.

SUGGESTED READING

1. Abbott P. Endodontic management of combined endodontic-periodontal lesions. J N Z Soc Periodontol. 1998;(83):15-28. Review.
2. Antrim DD, Bakland LK, Parker MW. Treatment of endodontic urgent care cases. Dent Clin North Am 1986; 30(3):549-72. Review.
3. Bonora F, Baroni C. [Iontophoresis in endodontic therapy: clinical and bacteriologic experiments] Arch Stomatol (Napoli) 1981;22(3):285-98.
4. Bucci E, Riccitiello F, Rengo S. [Healing of bone rarefaction by root canal therapy alone. II] Minerva Stomatol. 1987; 36(7-8):585-88.
5. Blanco-Moreno Lueje F, Ruiz de Temino Malo P, Folguera JO, Andonegui BZ. [Clinical cases: endo-periodontics. Diagnosis and treatment of primary endodontic lesions] Rev Esp Endodoncia 1984;2(3):123-27.
6. Badino M. [The problem of retreatment] Attual Dent 1989; 11;5(22-23):6-8,11-23. Italian. No abstract available.
7. Biggs JT, Miranda FJ. The management of endodontic emergencies. Compend Contin Educ Dent 1983;4(4): 313-19, 321.
8. Ford TR, Rhodes JS.Root canal retreatment: I. Case assessment and treatment planning. Dent Update 2004; 31(1):34-39.
9. Friedman S. Endodontic retreatment. Alpha Omegan 1990;83(4):32-7. Review.
10. Goldstein S, Sedaghat-Zandi A, Greenberg M, Friedman S. Apexification and apexogenesis. N Y State Dent J 1999; 65(5):23-25.
11. Gorostegui Etxabe J. [Endodontic retreatment] Rev Esp Endodoncia 1989;7(2):61-62.
12. Irmisch B, Voigt I. [Endodontic treatment of adolescent permanent teeth with special regard to incomplete root development] Stomatol DDR 1983;33(11):807-15.
13. Korzen BH, Pulver WH. Endodontic emergency treatment. Ont Dent 1978;55(6):15-19.
14. Machtou P, Friedman S, Stabholz A. [Rationale for endodontic retreatment] Rev Odontostomatol (Paris) 1988; 17(5):397-404.
15. Montgomery S, Ferguson CD. Endodontics. Diagnostic, treatment planning, and prognostic considerations. Dent Clin North Am 1986;30(3):533-48.
16. Pekruhn RB. The incidence of failure following single-visit endodontic therapy. J Endod 1986;12(2):68-72.
17. Reeh ES.Seven canals in a lower first molar. J Endod 1998; 24(7):497-99.
18. Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. J Endod 1990;16(10):498-504.
19. Selden HS. Endodontic radiographs: realities and illusions. Gen Dent 2000;48(5):594-97.
20. Sulte HR.Endodontic Irrigants. Northwest Dent 2004; 83(3):26-27.

Nanotechnology was first time revolutionized by Richard Feynman at his famous talk at annual meeting of the American physical society in 1959 entitled "There's plenty of room at the Bottom". He proposed using machine tools to make smaller machine tools, which in turn, would be used to make still smaller machine, tools and so on all the way down to the molecular levels. He suggested that such nanomachines, nanorobots and nanodevices could ultimately be used to develop a wide range of atomically precise microscopic instrumentation and manufacturing tools.

Nano is derived from νανοζ, the Greek word for dwarf. "Nano" refers to one billionth of a unit. A nanometer (nm) is one billionth of a meter or one thousandth of a millimeter (mm). A nanometer is about the size of 10 hydrogen atoms lined up "side-by-side" and 2.5 nanometers is about the width of a DNA molecule. The nanoscale is about a thousand times smaller than micro, which is about 1\80,000 of the diameter of a human hair.

The term "Nanotechnology" was coined by Prof. Kerie E. Drexler, a lecturer, researcher, and writer, in "Engines of Creation" (1986). It is also known as Molecular Nanotechnology or Molecular Engineering.

Definition of nanotechnology developed by the National Nanotechnology Initiative (NNI): "Nanotechnology is concerned with materials and systems whose structures and components exhibit novel and significantly improved physical, chemical and biological properties—and that enable the exploitation of novel phenomena and processes- due to their nanoscale size" (2000).

HOW ARE THE NANOPRODUCTS MADE?

Current research is directed towards the production of a wide array of different minuscule structures. The fabrication techniques of these structures can be divided into 2 approaches: "top- down" and "bottom-up".

A. The "TOP-DOWN" techniques produce very small structures from larger pieces of material. These are mostly extensions of methods already employed in small-scale assembly at the micron scale. By further miniaturization, the nanodimension is entered.
B. "BOTTOM-UP" fabrication methods—Drexler first described the "bottom-up" approach (atom by atom) to manufacturing large scale materials using nanobots capable of self-replication (i.e. Assemblers), in his book, Engines of Creation (1986).

NANOMEDICINE

"This is the science and technology of diagnosing, treating and preventing disease and traumatic injury, of relieving pain, and of preserving and improving human health, through the use of nanoscale structured materials, biotechnology and genetic engineering and eventually complex molecular machine system and nanorobots."

Feynman offered the first known proposal for nanomedical procedure to heart disease. He proposed that it would be interesting in surgery if you could swallow the surgeon. Put the mechanical surgeon / nanorobots into the blood vessel and it goes into the heart and looks around. In preprogrammed monitor

it finds out which valve is the faulty one and takes a little knife, slices it out and corrects it. Other small machines might be permanently incorporated in the body to assist some inadequately functioning organ.

Nanomedicine holds promise for:

1. Advanced diagnostics - Development of remote or in vivo diagnostics
2. Biosensors - for earlier disease detection
3. Targeted drug delivery
4. Improvement of natural physiological function.
5. Tissue engineering - to enhance success of tissue transplant or to create artificial tissues or organs.
6. Instant pathogen diagnosis and extermination using medical nanorobots (self-assembling nanostructures) to seek and destroy microorganisms.
7. The creation of nanoscale devices known as Nanorobots or more simply, Nanobots, would allow physicians to perform precise interventions at the cellular and molecular level. These nanobots have the potential to serve as vehicles for delivery of therapeutic agents, detectors or guardians against early disease and perhaps repair of metabolic or genetic defects (Fig. 26.1).

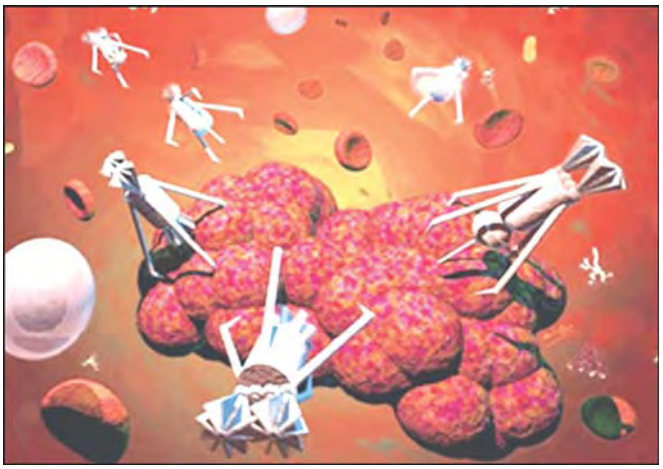


Fig. 26.1: Nanorobots attacking tumor cells

NANODENTISTRY

Nanodentistry will make possible the maintenance of comprehensive oral health by involving the use of:

i. Dental nanorobotics - Bottom-Up approach
ii. Nanomaterials - Top-Down approach
iii. Biotechnology (including Tissue engineering).

I. Applications of Nanorobotics to Dentistry

1. *Precisely controlled oral analgesia (Inducing anesthesia):* One of the most common procedures in dentistry is the injection of local anesthetic, which can involve long waits and varying degrees of efficacy, patient discomfort and complications.
   - To induce oral anesthesia in the era of nanodentistry, dental professionals will instill a colloidal suspension containing millions of active analgesic micrometer-sized dental nanorobot "particles" on the patient's gingivae.
   - After contacting the surface of the crown or mucosa, the ambulating nanorobots reach the dentin by migrating into the gingival sulcus and passing painlessly through the lamina propria or the 1- to 3-μm-thick layer of loose tissue at the cementodentinal junction.
   - On reaching the dentin, the nanorobots enter dentinal tubule holes that are 1 to 4 μm in diameter and proceed toward the pulp, guided by a combination of chemical gradients, temperature differentials and even positional navigation, all under the control of the onboard nanocomputer, as directed by the dentist

   Assuming a total path length of about 10 mm from the tooth surface to the pulp and a modest travel speed of 100 μm/s, nanorobots can complete the journey into the pulp chamber in approximately 100 seconds.

   Once installed in the pulp and having established control over nerve-impulse traffic, the analgesic dental nanorobots may be commanded by the dentist to shut down all sensitivity in any tooth that requires treatment. When the dentist presses the icon for the desired tooth on the hand-held controller display, the selected tooth immediately numbs.

   After the oral procedures are completed, the dentist orders the nanorobots to restore all sensation, to relinquish control of nerve traffic and to egress from the tooth via similar pathways used for ingress; following this, they are aspirated.
2. *Permanent hypersensitivity cure:* Dentin hypersensitivity may be caused by changes in pressure transmitted hydrodynamically to the pulp. This etiology is suggested by the finding that hypersensitive teeth have dentinal tubules with

surface number densities that are eight times higher than those of nonsensitive teeth, as well as tubules with diameters that are twice as large. (Absi, J Clin Periodontol, 1987).

Reconstructive dental nanorobots, using native biological materials, could selectively and precisely occlude specific tubules within minutes, offering patients a quick and permanent cure.

3. *Continuous oral health maintenance through the use of mechanical dentifrobots (Prevention - Nanorobotic dentifrice [dentifrobots]) (Fig. 26.2):* A subocclusal dwelling nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces at least once a day, metabolizing trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement. Properly configured dentifrobots could identify and destroy pathogenic bacteria residing in the plaque and elsewhere, while allowing the 500 or so species of harmless oral microflora to flourish in a healthy ecosystem.

With this kind of daily dental care available from an early age, conventional tooth decay and gingival disease will disappear.

II. Applications of Nanomaterials to Dentistry—Nanodentistry as Top-down Approach

A. Nanocomposites
B. Nanosolution - Adper Single Bond 2 adhesive
C. Covalently bonded diamondized enamel (Durability and appearance)
D. Impression Materials

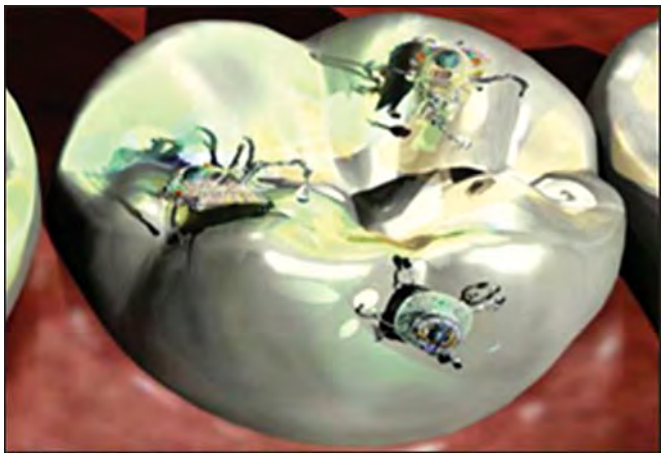


Fig. 26.2: Dentifrobots

E. Nanoencapsulation: SWRI [South West Research Institute] has developed Targeted Release Systems that encompass nanocapsules including novel vaccines, antibiotics and drug delivery with reduced side effects.

Other Products Manufactured by SWRI

i. Protective clothing and filtration masks—using antipathogenic nanoemulsions and nanoparticles
ii. Medical appendages for instantaneous healing
   - Biodegradable nanofibers—delivery platform for hemostasis
   - Wound dressings with silk nanofibres—In development
   - Nanocrystalline silver particles with antimicrobial properties on wound dressings
iii. Bone targeting nanocarriers—Calcium phosphate-based bone biomaterial has been developed. It is an easily flowable, moldable paste that conforms to and interdigitates with host bone and supports growth of cartilage and bone cells.

F. Bone replacement materials—Hydroxyapatite nanoparticles used to treat bone defects are:
   - Ostim - HA
   - NanOSS - HA
   - VITOSSO - HA +TCP

G. *Nanoneedles:* Suture needles incorporating nanosized stainless steel crystals have been developed.

Trade name: Sandvik Bioline, RK 91TM needles [AB Sandvik, Sweden].

Nanotweezers are also under development which will make cell-surgery possible in the future.

III. Biotechnology (Including Tissue Engineering) (Fig. 26.3)

When nanotechnology arrives within the next 10-20 years, it will put a halt to the genetics behind tooth loss, gum disease and bone loss in the jaw due to aging. Nanotechnology is being used in teeth and bone replacements by copying the way nature itself lays down minerals (this process is called Bio-Mimicry).

A. Dentition renaturalization (Renaturalization procedures)

Dentition renaturalization procedures may provide perfect treatment methods for esthetic dentistry. This trend may begin with patients who desire to have their old dental amalgams excavated and their teeth remanufactured with native biological materials.

Fig. 26.3: Biotechnology

However, demand will grow for full coronal renaturalization procedures in which all fillings, crowns and other 20th-century modifications to the visible dentition are removed, with the affected teeth remanufactured to become indistinguishable from the original teeth.

B. Dentition replacement therapy using biologically autologous whole replacement teeth manufactured during a single office visit (Major tooth repair)

Nanodental techniques for major tooth repair may evolve through several stages of technological development:

i. First using genetic engineering, tissue engineering and tissue regeneration
ii. Later involving the growth of whole new teeth in vitro and their installation
iii. Ultimately, the nanorobotic manufacture and installation of a biologically autologous whole-replacement tooth that includes both mineral and cellular components- that is, complete dentition replacement therapy- should become feasible within the time and economic constraints of a typical office visit, through the use of an affordable desktop manufacturing facility, which would fabricate the new tooth, in the dentist's office.

CONCLUSION

Nanotechnology will change dentistry, health care and human life more profoundly than many developments of the past. As with all technologies, nanotechnology carries a significant potential for misuse and abuse on a scale and scope never seen before. Nanodevices cannot be seen, yet carry powerful capabilities. However, they also have the potential to bring about significant benefits, such as improved health, better use of natural resources and reduced environmental pollution.

SUGGESTED READING

1. Baum BJ, Mooney DJ. The impact of tissue engineering on dentistry. JADA 2000;131:309-18.
2. Berkeley Lab Research Review (Fall 2001) articles /research review /magazine/2001/fall/index.html.
3. Drexler KE. Predicting and projecting. In: Drexler KE. Engines of creation: the coming era of nanotechnology. New York: Anchor Press/ Doubleday; 1986. Available at:" www. foresight. org/EOC/".
4. Drexler KE. Nanosystems: molecular machinery, manufacturing, and computation. New York: John Wiley and Sons; 1992.
5. Freitas RA Jr. Nanodentistry. JADA 2000;131:1559-65.
6. Hochman R. Neurotransmitter modulator (TENS) for control of dental operative pain. JADA 1988;116: 208-12.
7. Mehregany M, Tai Y-C. Surface micromachined mechanisms and micromotors. J Micromech Microeng 1991;1:73-85.
8. National Nanotechnology Initiative 2000 Leading to the Next Industrial Revolution. A Report by the Interagency Working Group on Nano science, Engineering and Technology (Washington, DC: Committee on Technology, National Science and Technology Council) http://www/ nano.gov
9. West JL, Halas NJ. Applications of nanotechnology to biotechnology. Curr Opin Biotechnol 2000;11(2):215-17.

27 Summary and Conclusion

In light of the various procedures often encountered in endodontic therapy, it is not surprising that research in endodontics has focused on the development of effective tools and materials to facilitate root canal treatment. While the technological advances in endodontics have been impressive, the biological basis for root canal therapy has been receiving more and more attention.

In recent years, gadgets that measure vitality of pulp based on blood flow have been effectively used in practice and the results of Laser Doppler Flowmetry and Pulse oximetry have been found reliable. Molecular biology techniques for the study of microbiology have advanced significantly to permit the identification of many new micro-organisms. The classic phenotypic identification has been replaced in many situations, by genotypic identification. This has provided new observations of significance for future research. Thus, in addition to the identification of new micro-organisms in the pulp space, it has also been possible to establish reliable information about their prevalence.

Access preparation has been revolutionized by the advent of new bur designs and ultrasonic tips. Advanced studies in root canal anatomy and morphology have led to the understanding of complexity of root canal system thus facilitating the clinical treatment. Badly broken down teeth can now be restored using pre-endodontic restoration, i.e. Endodontic Projection system. Electronic root canal length determination equipments have been designed to locate the apical foramen more accurately than ever before.

Preparation of root canal systems includes both enlargement and shaping of the complex endodontic space, together with its disinfection. Advent of Ni-Ti rotary instruments in endodontics, which have varying tapers, facilitate easy instrumentation in curved root canals. New irrigating solutions like MTAD and chlorine dioxide can efficiently remove E. fecalis from the root canal. Plethora of new obturation systems like Gutta Flow and Resilon-Epiphany have been introduced in the market with improved properties.

Dental operating microscope in the last 10 years has progressed from a novelty item to the required training standard in endodontics. Ultrasonic and lasers can be used for multiple procedures in root canal treatment. Developments of tissue engineering concepts in endodontics are under research and are thought to eventually replace conventional root canal treatment.

To conclude, the explosive development of new technology in endodontics, as well as innovative solutions to the previously unanswered questions, are being developed and will continue at an exponential rate well into this new era. Although the latest tools for performing endodontics have elevated the specialty to a sophistication attained never before, many of the areas DO remain that require significant advancement and research which may be undertaken in the near future.

Index

A

Accessory foramen 115
Accidental trauma to the dentition 288
  avulsion
    definition 297
    management 298
    preparation of root 298
  classification 288
    Andreasen's modification 289
    classification by Hargreaves 292
    modification of Ellis classification 292
    WHO classification 289
  complicated crown fractures 296
  crown fractures 49, 294
  dentin fractures
    clinical presentation 295
    diagnosis 295
    treatment 295
  enamel fractures
    biologic consequences 294
    clinical presentation 294
    diagnosis 294
    treatment 294
  epidemiology
    seasonal variations 292
    sex and age distribution 292
  etiology 292
  extrusive luxation 297
  intrusive luxation 297
  mechanisms of dental injuries 293
    direction of the impacting force 294
    enamel prisms 294
    energy of impact 293
    resilience of the impacting object 293
    shape of the impacting object 293
  predisposing factors 292
  recent classification by WHO 289
    injuries to gingiva (or) oral mucosa 291
    injuries to the hard dental tissues and the pulp 289
    injuries to the periodontal tissues 291
  root fracture
    healing or repair 298
    healing with calcified tissue 299
    interposition of bone 299
    interposition of connective tissue 299
    interposition of granulation tissue 300
Actinomyces 69
Adjunctive therapy 52
Alveolar abscess 42, 47
  definition 47
  signs and symptoms 42
  treatment 48
Apex locators 124
  classification
    first generation 125
    fourth generation 130
    second generation 125
    third generation 126
  clinical acceptance 131
  contraindications 131
  effect of different metal types 131
  mode of action 124
  other uses 131
Apexification
  contraindications 102
  definition 102
  indication 102
  matrials and method 102
  new materials used 103
Apexogenesis 100, 102
Apical closure pulpotomy 100
Apical constriction 116
Apical periodontitis 41, 47
  causes 42, 47
  clinical features 42
  definition 47
  histopathology 42
  symptoms 47
  treatment 48
Apicoectomy 261
Autoclave 87
Avulsion 51, 297

B

Bacteria 32, 61
  structure 62
Barodontalgia 31
Biofilm 64
  antimicrobials and biofilm 65
  biofilm on root canal surfaces 65
  stages of biofilm formation 65
Bleaching of teeth 307, 312
  bleaching lights 322
  bleaching of non-vital teeth 307, 319
    in-office bleaching 320
    in-office-power bleaching 322
    other methods of non-vital bleaching 321
    out of office bleaching 320
    over the counter systems 322
  bleaching of vital teeth 307, 315
  definition 307
  factors influencing tooth whitening 324
  histologic effects 314
  instruments 314
  measurement of tooth whitening 323
  mechanism of action 312
  preparation 314
  treatment planning 314

C

Calcium hydroxide 98
Calcium hydroxide pulpotomy 101
Causes for endodontic failure 341
  access opening 343
  biomechanical preparation 344
  broken instrument 344
  case selection 341
  instrument removal system 346
  Masserann kit 347
  obturation
    chemical method 349
    mechanical method 350
    removal of pastes and cements 351
    removal of silver points 350
    thermal removal 349
  other systems: Ruddle's kit 347
    elbow formation 348
    improper cleaning and shaping of the canals 349
    improper use of irrigating solutions 349
    ledge formation 347
    management 348
    zipping 349
  post removal 351
  removal of esthetic posts 352
  roydent endo-extractor 346
  Ruddle's instrument removal system 347
Cementoma 43
Cervical pulpotomy 101
Cold test 8
Condensing osteitis 44
Coronal leakage 222

definitive treatment 224
establishment of atraumatic occlusion 224
long-term follow-up 224
prevention 222
temporary seal of the root canal system 222
timeliness in restoration 224
Cracked tooth syndrome 30, 49
Crown fractures 49, 53, 294
Culture methods and media 71
anaerobic 75
complex 71
differential 72
enriched 71
enrichment 71
indicator 71
proteus 71
selective 71
simple 71
synthetic 71
transport 72
Curved canals 121

D

Dental cyst 42
Dentin bonding agents 99
Dentin fractures 295
Dentoalveolar ankylosis 304
Diagnostic methods in endodontics 1
clinical examinations
extraoral 2
intraoral 2
dental history 1
medical history 1
pain 1
duration 2
factors which provoke/relieve 2
localization 2
type 2
recent methods 3
anesthetic test 9
blood flow determination devices 3, 11
cold test 8
electric devices 3, 9
imaging techniques 3
mobility and depressibility tests 6
orascopy or endoscopy 16
palpation 5
percussion 5
periodontal examination 6
radiographic techniques 17
surface temperature measurement devices 3
test cavity 9
thermal devices 3
thermal tests 7
transillumination devices 3
transilluminations 15
visual and tactile inspection 4
ultrasound imaging 22
computerized expert system 27
computerized tomography 23
magnetic resonance imaging 26
tuned aperture computed tomography 25
xenon-133 with radiolabeled microspheres 27
Digital radiography 18
subtraction 21
Discoloration of tooth
extrinsic 308
intrinsic 308
discoloration as a symptom 311
discoloration due to aging 311
discoloration due to heredity 311
discoloration from pulp necrosis 310
fluorosis staining 309
iatrogenic discoloration 310
tetracycline staining 308
Disease of the pulp 32
Disinfection 85
Displacement of the tooth 297
Dry heat 86
Dual wavelength spectrophotometry 13

E

Electric pulp testers 9
Electronic thermography 15
Enamel fractures 294
Endodontic flare ups 52
Endodontic implants
case selection 335
causes for the failure 335
indications 335
instruments used 336
materials used 336
procedure 336
Endodontic instruments 141
advances in hand instruments nickel-titanium files 145
endo sequences 171
flex master 165
flex O files 145
flex R file 145
hedstroem files 144
HERO-642 164
ISO group II and III instruments 147
canal finder system 149
cavitron endodontic system 150
EMS piezon master 151
endo-gripper handpiece 149
giromatic handpiece 148
handpieces 147
helical angle 153
M4 safety handpiece 148
nickel-titanium instruments 152
rake angle 153
reciprocating handpiece 148
reduction gear handpiece 147
rotary handpiece 147
sonic handpieces 151
tri auto ZX 147
ultrasonic handpiece 150
vertical stroke handpiece 149
K flex file 145
K reamer 144
K3 file system 168
K-file features 144
liberator 173
light speed endodontic instruments 155
orifice opener 157
orifice shapers 158
pow-R nickel-titanium rotary files 161
profile series 29 157
profile systems 157
prosystem GT instruments 159
proTaper system 166, 168
finishing files 167
shaping files 166
quantec system 162
quantec hand files 162
quantec rotary files 162
race (reamer with alternative cutting edges) 165
rapid body shapers 161
rotary instruments 155
taper rotary instruments 157
techniques for preparation root canals
apicocoronal method 174
coronoapical method 175
crown down preparation 177
V-taper files 172
wide radial lands 169
Endodontic microbiology 66
association of specific bacteria 68
microbiological status of root filled teeth 67
microflora
acute infections 67
endodontic flare-up infections 67
pulp space 67
routes of microbial entry to the pulp
bloodstream 66
direct access 66
pulpo-periodontal pathway 66
Endodontic microsurgery 256

advantages of microscopes 258
accessories 259
documentation 259
illumination 259
magnification 258
comparison of traditional and micro-surgery 257
contraindications to surgical endodontics 261
dental operating microscope 257
endodontic surgery procedure 265
graft materials used 283
bio-Oss collagen 284
cerasorb 284
osteogenic proteins 283
osteograf/N 284
platelet growth factors 283
safety and bio-compatibility 284
hard tissue management 268
bur design 270
coolant 269
cutting speed 269
effect of heat 269
osteotomy 268
proximity to the anatomic structures 270
indications for endodontic surgery 260
magnification and illumination 256
methylene blue staining 274
micromirrors 263
microsurgical armamentarium 261
mineral trioxide aggregate 277
collagen 280
comparing calcium hydroxide and MTA 278
gut 280
polyglactin 281
repositioning and compression 280
soft-tissue repositioning and suturing 280
periradicular curettage 271
instrumentation and technique 274
length of the resected root face 272
root end resection 272
postoperative care 285
postoperative sequelae 285
prerequisites for the use of microscope 257
root end preparation procedure 275
root end filling 277
ultrasonic root end preparation 275
soft tissue management 265
palatal flaps 268
papilla-base flap 267
principles and guidelines for flap design 265
rectangular and trapezoidal flap 266
semilunar flap 265
submarginal flap 267
triangular flap 266
suture removal 285
suturing 281
needle selection 281
silk 281
suture techniques 282
uses of dental operating microscope 259
Enterococcus 69
Ethylene oxide sterilizer 87

F

Fiberoptic transilluminations 15
Fracture of the crown 49, 53, 249
Frictional heat during polishing 31

H

Heat conduction by fillings 31
Heat test 7
Hot-salt sterilizer 88
Hughes probeye camera 14

I

Incineration 86
Incision and drainage 48
Inflammation 55
causes 55
cellular changes 56
basophils and mast cells 57
eosinophils 57
lymphocytes 56
macrophages 56
neutrophils 56
definition 55
endodontic implications 59
periradicular manifestations 58
signs and symptoms 55
types 55
vascular changes 57
Inflammation of the pulp 32
Internal resorption 38
Interpretation of radiographic findings 79
bisecting angle technique 80
paralleling technique 80
Intracanal medicaments 180
antibiotics and steroids 184
antimicrobial effectiveness 184
classifications 180
frequency of medication 184
ideal requirements 180
individual intracanal medicaments 181
calcium hydroxide 183
camphorated paramonochlorophenol 181
cationic detergents 183
creosote 182
cresatin 182
eugenol 182
formocresol 181
glutaraldehyde 182
halogens 183
heavy metal salts 182
iodides 183
monochlorophenol 181
sodium hypochlorite 183
ledermix paste 184
mode of action 181
polyantibiotic paste 184
Irrigating solutions
ideal requisites 133
rinsEndo irrigation system 137
safety irrigator 137
solutions 134
chelating agents 135
chlorhexidine gluconate 135
chlorine dioxide 136
decalcifiers 136
glyoxide 135
hydrogen peroxide 134
iodine potassium iodide 137
MTAD 136
saline 134
sodium hypochlorite 134
ultrasonic irrigating systems 137
Isolation 81

L

Lactobacilli 69
Laser 326
application in dentistry 329
access cavity preparation 330
apicoectomy 333
closure of apical foramina of root canals 332
direct pulp capping 330
enlargement of the root canal orifice 330
for vital pulp amputation 330
indirect pulp capping 329
irrigation in combination 332
laser treatment under a fiberscope 333
periapical curettage 333
periapical lesions of sinus tract 333
removal of temporary cavity sealing material 333
removing pulp remnants and debris 331

retrograde endodontic apical cavity preparation 333
root canal cleaning 332
root canal filling 333
root canal wall preparation 331
sterilization or disinfection of infected root canals 332
strengthening of the root canal wall 332
desensitization of hypersensitive dentin and teeth 328
CO_2 laser 329
pulsed Nd: YAG laser 329
semiconductor diode laser 328
emission modes and delivery 327
interaction of living tissue 327
lasers used in endodontics 327
argon 328
carbon dioxide 328
Er:YAG 328
ErCr: YSGG 328
gallium-aluminum (GaAlAs) semiconductor diode 327
helium-neon 328
neodynium yttrium aluminum garnet 328
spectrum and wavelengths 327
Laser Doppler flowmetry 11
Liquid crystal testing 14
Local anesthetics 92
available products 93
classification 92
commonly used agents
adrenaline 94, 95
articaine hydrochloride 95
bupivacaine 94
etidocaine 95
levonordefrin 94
lidocaine 94
mepivacaine 94
prilocaine 94
mechanism of action 93
nomenclature 94
undesired effects
cardiovascular system 95
central nervous system 95
hypersensitivity/allergy 95
methemoglobinemia 96
treatment of overdose:lipid rescue 95
vasoconstrictors in LA 93

M

Management of badly broken down tooth 112
Methylene blue staining 274
Microbiological diagnosis in endodontics 73
gene targets for microbial identification 75
immunological methods 74
microscopy 73
molecular genetic methods 74
traditional identification methods 73
Microbiology 61
Microorganisms 61
Mid treatment emergencies 52
Mineral trioxide aggregate 100, 277
Mobilometers 6

N

Nanodentistry 354
applications of nanomaterials 355
applications of nanorobotics 354
biotechnology 355
Nanomedicine 353
Necrosis of pulp 41

O

Obturation 198
clinical pictures
active GP system 219
dentin chip apical filling 220
endo REZ system 219
cold lateral condensation
selection of the master cone 199
denseful thermal endodontic obturation system 212
different techniques 198
endotwinn
handpiece 203
tip plugger 203
tip spoon 204
tip spreader 204
engine plugger 206
gutta flow manipulation 218
gutta flow system 217
light speed method 211
Maillefer gutta condenser 205
Mcspadden compactor 204
objectives 198
prerequisites 198
simplified alterations to the existing systems 217
soft-core obturator for foot filling 213
solid core carrier obturation 209
size verification 210
thermafil 209
thermafil plus obturators 211
thermafil plus oven 211
system B 202
thermocompactors 204
thermoplasticized gutta-percha techniques 206
back filling technique 207
calamus flow obturation delivery system 208
injection techniques 206
microseal system 208
obtura system 206
precision apical control 207
ultrafil 206
trifecta system 212
ultrasonic plasticizing
cavitron with PR-30 insert 214
ENAC 214
resilon 214
warm vertical condensation method 200
zipper thermocompactor 206
Oral hygiene 79
Orascopy or endoscopy 16
Ossifying fibroma 44
Osteotomy 268
Over obturation/under obturation 53

P

Pain and swelling 48
Pasteurization 86
Pathologic wear 30
Periapical cyst 42
Periapical granuloma 43
Periodontal abscess 48
Periradicular curettage 271
Polymerase chain reaction 75
limitations of PCR-derived technologies 78
method of culture taking 76
denaturin G grandient gel electrophoresis 76
DNA microarrays 77
DNA-DNA hybridization 77
fluorescence *in situ* hybridization 77
terminal-RFLP 77
types
broad-range 76
multiplex 76
nested 76
real-time 76
reverse transcriptase 76
Post 226
active retention posts 237
parallel threaded posts 240
posts with self-threading screws 238
self-threading parallel-threaded posts 239
clinical technique 241, 243
all-ceramic post and core 243

ceramic and zirconium posts 242
glass fiber and other fiber reinforced posts 242
non-metallic posts 241
occlusal forces 244
remaining coronal tooth structure 243
root morphology 243
components 227
conservation of tooth structure
coronal tissue 229
root canal 229
contraindications 226
core fabrication
cast-metal core 249
cementation of preformed posts 253
composite resin cores 251
custom-made posts 253
investing and casting 252
plastic filling materials 250
prefabricated posts 253
try-in and cementation 253
Wiptam technique 254
enlargement of the canal 245
for custom-made posts 246
for pre-fabricated posts 246
final restoration 255
functions 227
ideal properties 227
indications 226
material requirements 228
materials used 228
metal posts
custom-cast metal posts 233
materials used 234
passive retention posts 235
boston post system 237
parallel-sided posts 235, 237
para-post system 236
Parkell parallel post system 237
tapered smooth-sided posts 235
post fabrication 247
custom-made posts 248
prefabricated posts 247
prefabricated posts 234
preparation of coronal tooth structure 247
removal of the endodontic filling material 244
removal with a heated endodontic condenser 245
removal with rotary instruments 244
resistance form 231
ferrule 232
rotational resistance 232
stress distribution 231
retention form 229
considerations for posterior teeth 231
types 228
Post-endodontic emergencies 53
Pulp capping 97
ideal properties of material 98
types
direct pulp cap 97
indirect pulp cap 97
Pulp degeneration 39
atrophic degeneration 40
calcific degeneration 39
fibrous degeneration 41
pulp stones 39
tumor metastasis 41
Pulpal reaction to fillings 31
Pulpitis 32, 46
chronic hyperplastic 37
cause 33, 37
definition 37
diagnosis 33, 37
differential diagnosis 34, 38
histopathology 33, 37
prognosis 34, 38
symptoms 33, 37
treatment 34, 38
irreversible 34, 47
cause 35
definition 34
diagnosis 36
differential diagnosis 36
histopathology 35
prognosis 36
symptoms 35
treatment 36
reversible 32, 46
causes 46
definition 32, 46
treatment 47
Pulpotomy with MTA 101
Pulseoximeter 12

R

Radicular cyst 42
Reference points 116
Referred pain 50
Resorption of root 301
external 303
cervical root 305
inflammatory 304
replacement reabsorption 304
surface root 303
internal 301
non-perforating 302
perforating 302
Root canal cultures 72
Root canal 105
access cavity preparation
anterior 107
posterior 108
anatomic variations in mandibular molars
C-shaped canals 110
middle mesial canal 110
radix entomolaris 110
classification of canal morphology
Vertucci's 106
Weine's 106
MB-2 canal in maxillary molar 109
recent developments in materials used
endo access bur 111
endo Z bur 111
great whites 111
LN bur, muller bur 111
multi-purpose 112
transmetal bur 111
root canal access preparation 108
variations in root canal morphology 109
Root canal sealers 186
advantages of ZnOE cement 188
AH plus jet 190
biocalyx 193
calcium hydroxide cements 191
definition 186
diaket 190
endofill 191
endomethasone 191
functions 186
hydron (injectable cement) 190
ideal requirements 186
iodoform 193
kerr root canal sealer/Rickert's formula 187
newer sealers 193
apatite root canal sealer 195
bioseal 195
calcium phosphate type sealers 195
endoflas 193
epiphany sealer 195
hydrox 195
ketax-endo glass ionomer 194
nogenol 191
non-eugenol sealers 189
AH-26 189
kloroperka N-sealer 189
seal apex 192
SPAD 192
tests for proper consistency 188
vitapex 192
Root fracture 49, 298
Rubber dam 81

application technique 83
frame 81
punch 82
sheets 82
template 82

S

Stem cells 337
Sterilization 85
cold chemical sterilization 88
ethylene oxide sterilizer 87
glass-bead sterilizer 89
heat 86
hot-salt sterilizer 88
steam under pressure 87
sterilization by radiation 89
Streptococci 68

T

The isthmus 274
Thermal injury 31
Thermal tests 7
Tissue engineering 337
function of adult stem cell 338
goals of stem cell therapy
morphogens 338
scaffold 338
source of pulp stem cells 338
stem cell therapy 338
vascular regeneration 340
stem cells 337
Transmitted-light photoplethysmography 13
Traumatic injury 30

V

Veillonella 69
Virus 63
dimorphic fungi 64
moulds 64
structure 64
yeast like fungi 64
yeasts 64
Vital pulp therapy 100

W

Working length 115
historical perspectives 117
methods of determining 118
radiographic method 118
audiometric methoid 123
best method 121
Bramante method 122
Bregman method 121
Grossman's method 118
Ingle's technique 118
paper points 124
Weine's modification 121
significance 115

X

Xeroradiography 18