

www.azadmed.com



 azaadtejaratpars

 @azadmed2

 88 98 80 63 - 6

Journal of

Oral Science & Rehabilitation

Journal for periodontology, implant dentistry,
dental prosthodontics and maxillofacial surgery

ISSN 2365-6123 (Print)

ISSN 2365-6891 (Online)

Volume 3 — Issue 1/2017

dti Dental
Tribune
International



Essential Dental Media

Dental Tribune International

The World's Largest News and Educational Network in Dentistry

www.dental-tribune.com

dti Dental
Tribune
International

ADMED
.com

Journal of

Oral Science & Rehabilitation

On research and education

Reference

**García-Gallego A,
Georgantzis N,
Martín-Montaner J,
Pérez-Amaral T**

(How) do research and administrative duties affect university professors' teaching?
Appl Econ.
2015 May 5;47(45):4868–83.

It is well proven that research and education constitute a positive feedback system. A recent study among 609 university professors concluded that educators who carry out frequent research activities perform significantly better at their teaching activities.¹ This is equally true when seen from the student perspective. Research is itself a very powerful educational tool. Being involved in research activities takes students to a level of critical thinking and in-depth study that can rarely be achieved with other educational methods. Even more importantly, science itself would certainly benefit from the involvement of students in research, as they will always bring with them fresh and challenging ideas and enthusiasm.

For all these reasons, educational plans and educators should ensure that undergraduate and postgraduate students have the opportunity to participate in research activities as early as possible.

Dr. David Peñarrocha Oltra
Associate Editor

03

Editorial

Dr. David Peñarrocha Oltra

06

About the *Journal of Oral Science & Rehabilitation*

08

Marco Tallarico et al.

Comprehensive rehabilitation and natural esthetics with implant and orthodontics (CRANIO): An interdisciplinary approach to missing maxillary lateral incisors

18

Alberto Monje and Hom-Lay Wang

Biological and physical properties of bone block grafting biomaterials for alveolar ridge augmentation

32

Jörg-Ulf Wiegner et al.

Retrospective analysis of periimplantitis therapy of 158 implants

44

Masataka Hirose et al.

Bone augmentation of canine frontal sinuses using a porous α -tricalcium phosphate for implant treatment

52

Natalia Ribes Lainez et al.

Importance of a preoperative radiographic scale for evaluating surgical difficulty of impacted mandibular third molar extraction

60

Andrea Papini et al.

Kinesiographic analysis of lateral excursive movement on the horizontal plane: the retrusive component

68

Marco Tallarico and Silvio Meloni

Open cohort prospective study on early implant failure and physiological marginal remodeling expected using sandblasted and acid-etched bone level implants featuring an 11° morse taper connection within one year after loading

80

Guidelines for authors

82

Imprint — about the publisher



MASTER OF ORAL IMPLANTOLOGY PROGRAM

📍 San Diego, California

📅 One-year and two-year tracks available

ADVANCED SURGICAL & PROSTHETIC IMPLANT TRAINING PROGRAM



The advanced surgical & prosthetic *Master of Oral Implantology Program* is designed for general dentists of all implant experience levels, as well as specialists in the fields of prosthodontics, periodontics and endodontics. The goal of the program is to provide doctors with the right tools for a successful career in implant dentistry.

The California Implant Institute and its world-renowned faculty have developed the most comprehensive curriculum focusing on essential information that is immediately useful to doctors, their staff, and their patients. Through in-class interactive lectures, online webinars, hands-on laboratory sessions, live-patient surgical experiences, and much more, participants will gain the highest level of knowledge and technical skills necessary to provide safe, appropriate, and efficient treatments.

Understanding the value of the time invested to complete the Master of Oral Implantology Program, CII offers a unique opportunity for doctors to fully customize their program track to best fit their availability while having the least impact on their practice.

Visit the CII website for detailed curriculum and schedules.

Faculty Members



Louie Al-Faraje, DDS

Diplomate, American Board of Oral Implantology
Academic Chairman, California Implant Institute



Mamaly Reshad, DDS, MSc

Former Section Chair for Fixed Prosthodontics and
Operative Dentistry, University of Southern California



Christopher A. Church, MD

Diplomate, American Board of Otolaryngology
Director, Loma Linda University Sinus and Allergy



James L. Rutkowski, DMD, PhD

Diplomate, American Board of Oral Implantology
Past President, American Board of Oral Implantology



Patrick Palacci, DDS

Head of Brånemark Osseointegration Center
in Marseille, France



Domenico Cascione, CDT, B.S.

President of OPERART LLC, a dental laboratory
in Santa Monica, California

Training Overview

The Program consists of 7 modules for a total of 1,000 CE units:

- **Didactic / In-Class Lecture Module**
Over 60 days of interactive academic learning
- **Live-Patient Surgical Module**
Perform 30+ surgical implant placements and
20+ bone grafting procedures
- **CAD/CAM Computer Guided Module**
Hands-on workshop focused on implant surgery
- **Implant Prosthodontics Module**
Hands-on implant-oriented occlusion workshop
and on-site shadowing of a Prosthodontist
- **Hands-On Cadaver Module**
- **Oral Sedation Certification Module**
- **Academic and Research Module**



www.implanteducation.net

info@implanteducation.net

+1 858.496.0574

About the *Journal of Oral Science & Rehabilitation*

The aim of the *Journal of Oral Science & Rehabilitation* is to promote rapid communication of scientific information between academia, industry and dental practitioners, thereby influencing the decision-making in clinical practice on an international level.

The *Journal of Oral Science & Rehabilitation* publishes original and high-quality research and clinical papers in the fields of periodontology, implant dentistry, prosthodontics and maxillofacial surgery. Priority is given to papers focusing on clinical techniques and with a direct impact on clinical decision-making and outcomes in the above-mentioned fields. Furthermore, book reviews, summaries and abstracts of scientific meetings are published in the journal.

Papers submitted to the *Journal of Oral Science & Rehabilitation* are subject to rigorous double-blind peer review. Papers are initially screened for relevance to the scope of the journal, as well as for scientific content and quality. Once accepted, the manuscript is sent to the relevant associate editors and reviewers of the journal for peer review. It is then returned to the author for revision and thereafter submitted for copy editing. The decision of the editor-in-chief is made after the review process and is considered final.

About Dental Tribune Science

Dental Tribune Science (DT Science) is an online open-access publishing platform (www.dtscience.com) on which the *Journal of Oral Science & Rehabilitation* is hosted and published.

DT Science is a project of the Dental Tribune International Publishing Group (DTI). DTI is composed of the leading dental trade publishers around the world. For more, visit

www.dental-tribune.com



Benefits of publishing in the journal for authors

There are numerous advantages of publishing in the *Journal of Oral Science & Rehabilitation*:

- Accepted papers are published in print and as e-papers on www.dtscience.com.
- Authors' work is granted exposure to a wide readership, ensuring increased impact of their research through open-access publishing on www.dtscience.com.
- Authors have the opportunity to present and promote their research by way of interviews and articles published on both www.dtscience.com and www.dental-tribune.com.
- Authors can also post videos relating to their research, present a webinar and blog on www.dtscience.com.

Subscription price

€50.00 per issue, including VAT and shipping costs.

Information for subscribers

The journal is published quarterly. Each issue is published as both a print version and an e-paper on www.dtscience.com.

Terms of delivery

The subscription price includes delivery of print journals to the recipient's address. The terms of delivery are delivered at place (DAP); the recipient is responsible for any import duty or taxes.

Copyright © 2016 Dental Tribune International GmbH. Published by Dental Tribune International GmbH. All rights reserved. No part of this publication may be reproduced, stored or transmitted in any form or by any means without prior permission in writing from the copyright holder.

Comprehensive rehabilitation and natural esthetics with implant and orthodontics (CRANIO): An interdisciplinary approach to missing maxillary lateral incisors

Marco Tallarico,^a Cesare Luzi,^b Giorgia Galasso,^c
Roberta Lione^d & Paola Cozza^d

^a Private practice, Rome, Italy; Surgical, Micro-Surgical and Medical Science Department, University of Sassari, Sassari, Italy; and Osstem AIC, Italy

^b Private practice, Rome, Italy; and Department of Orthodontics, University of Ferrara, Ferrara, Italy

^c Orthodontics Postgraduate Training Program, Department of Pediatric Surgery, Bambino Gesù children's hospital, Rome, Italy

^d Department of Clinical Sciences and Translational Medicine, University of Rome "Tor Vergata," Rome, Italy; and Department of Dentistry, "Nostra Signora del Buon Consiglio" University, Tirana, Albania

Corresponding author:

Dr. Marco Tallarico

Via di Val Tellina 116
00151 Rome
Italy

T +39 328 075 8769
me@studiomarcotallarico.it

How to cite this article:

Tallarico M, Luzi C, Galasso G, Lione R, Cozza P. Comprehensive rehabilitation and natural esthetics with implant and orthodontics (CRANIO): an interdisciplinary approach to missing maxillary lateral incisors. J Oral Science Rehabilitation. 2017 Mar;3(1):8–16.

Abstract

Background

The absence of the maxillary lateral incisors creates a functional and esthetic problem that can be managed with different treatment modalities.

Case presentation

The present case is reported to illustrate an interdisciplinary approach involving orthodontics and restorative dentistry to manage the case of a 24-year-old Caucasian female with agenesis of the maxillary right lateral incisor, presence of the maxillary right canine in place of the lateral incisor, microdontia of the maxillary left lateral incisor, and midline deviation. Treatment included space opening and positioning of a 3 mm implant supporting a single-unit crown, placed using computer-assisted, template-guided surgery.

Conclusion

Comprehensive interdisciplinary rehabilitation according to the CRANIO philosophy was effective in successfully restoring function and esthetics in a young female patient affected by congenitally missing maxillary lateral incisor.

Keywords

Interdisciplinary treatment, agenesis, dental esthetics, dental implants, guided surgery.

Introduction

Congenital tooth agenesis is a common dental anomaly, with reported incidences of 2.7% to 12.2%, excluding third molars. In the permanent dentition, maxillary lateral incisors are the most commonly affected,¹ with a prevalence rate of between 1% and 4%² and a female predominance of approximately 2:1 compared with males.³ This anomaly is not usually an isolated phenomenon, but is associated with other dental anomalies, such as peg-shaped contralateral incisors.¹ Therefore, the concurrence of several dental anomalies in the same subject results in functional and esthetic problems, which may in turn affect the patient's self-confidence and social relationships from a very young age.

Treatment options for missing lateral incisors include space opening, followed by the placement of a conventional fixed bridge or a single-unit implant-supported crown, and orthodontic space closure with anatomical recontouring of the canines.⁴ Selecting the most appropriate therapy is still a challenge. Numerous clinical characteristics must be analyzed, such as the patient's age, occlusal relationships, profile, smile line, presence or absence of third molars, and size, shape and color of the canines.⁵

In order to maximize the esthetic and functional results, an interdisciplinary approach involving an orthodontist, an oral surgeon and a restorative dentist has become essential. Comprehensive rehabilitation and natural esthetics with implant and orthodontics (CRANIO) is a philosophy based on interdisciplinary treatments to achieve stable occlusion and healthy hard and soft tissue and to enhance the natural esthetic appearance and subsequent patient satisfaction.

The aim of the present study was to describe an interdisciplinary approach to a clinical case presenting with a missing maxillary lateral incisor treated in two phases: orthodontic space opening, followed by placement of a narrow 3 mm diameter implant and restored with a screw-retained lithium disilicate crown veneered on a zirconia abutment.

Case report

A 24-year-old Caucasian female was referred to our private clinic to seek a second opinion for treatment, with the chief complaint of an unattractive smile and the mobility of the primary

maxillary right canine. Clinical examination and radiographs confirmed the advanced root resorption of the primary maxillary right canine, the agenesis of the permanent maxillary right lateral incisor, with the presence of the permanent canine in place of the lateral incisor, and microdontia of the maxillary left lateral incisor (**Figs. 1a–c**). Intraoral observation revealed an Angle Class II relationship of the molars and canine, an increased overjet, a normal overbite and a lower dental midline that was displaced 3 mm to the left compared with the upper midline.

Cephalometric analysis (Dolphin Imaging 11.7, Dolphin Imaging and Management Solutions, Chatsworth, Calif., U.S.) highlighted a mesofacial facial pattern, with a Class II sagittal skeletal relationship (**Fig. 2**). The patient presented with a symmetrical and proportional face and flat facial profile, with the upper lip positioned 4 mm and the lower lip 2 mm behind the Ricketts E-line.

The previously proposed treatment was extraction of the primary canine with space maintenance for a future implant rehabilitation and canine substitution with a veneer restoration. In contrast to this, the alternative treatment proposed was extraction of the primary canine, followed by orthodontic space recovery for implant placement in the lateral incisal area, with alignment and leveling of the dental arches. The option of correcting the Class II relationship would have required orthognathic surgery, which was refused by the patient.

The patient was initially very skeptical toward such a comprehensive treatment option. However, after discussion with both the orthodontist (CL) and implantologist (MT) of the advantages and disadvantages of all of the available treatment options, it became clear to the patient that the overall advantages of the proposed interdisciplinary treatment, involving orthodontic treatment, implant placement and prosthetic rehabilitation, would provide improved esthetic and functional results. The disadvantages of the proposed treatment were related to costs and a longer treatment time.

The orthodontic treatment lasted 18 months. After the extraction of the primary canine, full-arch bonding with a fixed esthetic multibracket appliance was performed, and the maxillary right canine was strategically bonded with a mesial tip back to enhance root control. Skeletal anchorage by means of an orthodontic miniscrew (Aarhus System, American Orthodontics, Sheboygan, Wisconsin, U.S.; 1.5 mm diameter,



Figs. 1a & b



Fig. 1c

Figs. 1a-c
Preoperative intraoral view:
frontal (a), right (b) and left (c).

Fig. 2
Cephalometric analysis.

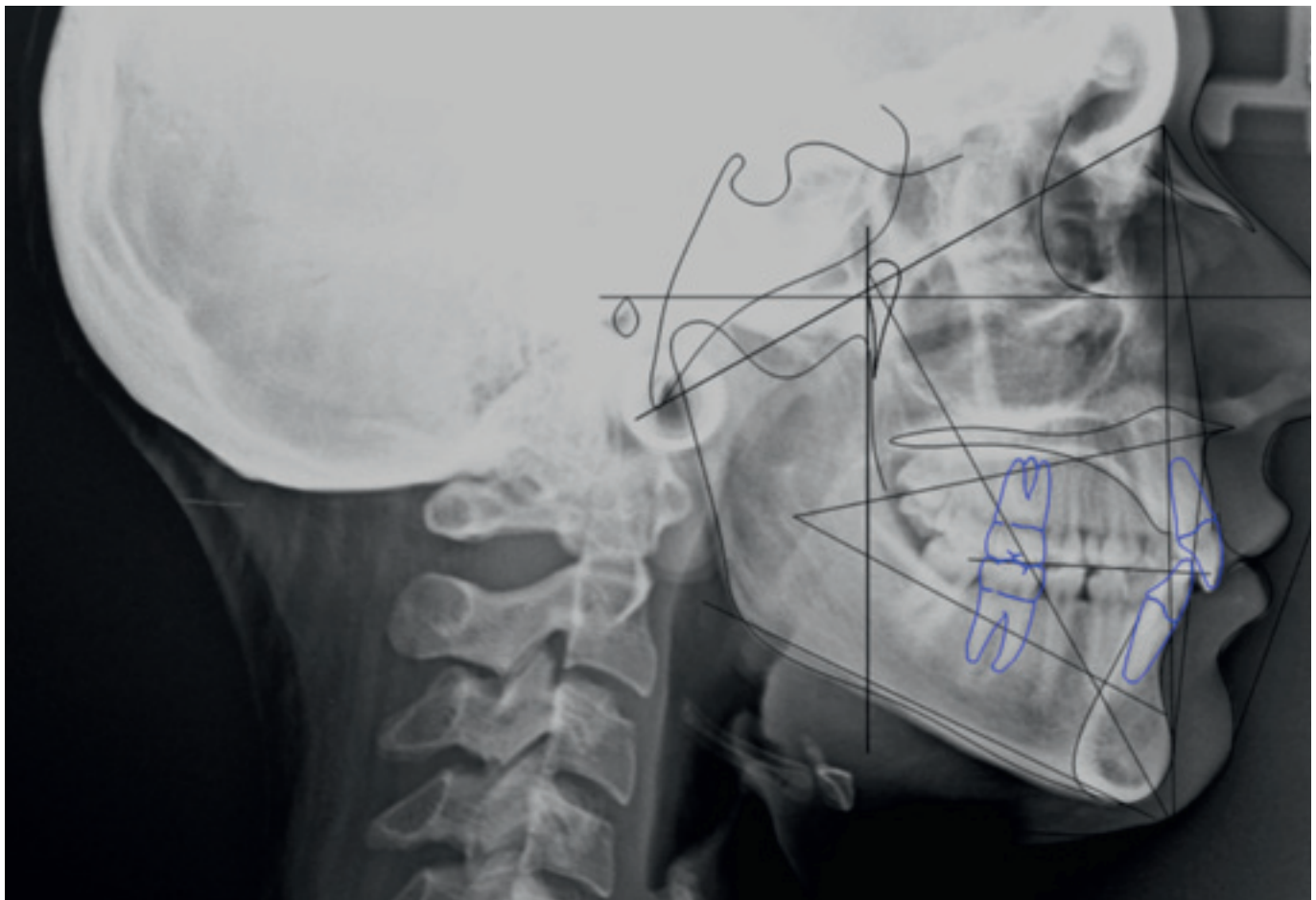


Fig. 2

6.0 mm thread length) was used during canine retraction with sliding mechanics to avoid side effects (i.e., worsening of the molar relationship). Both direct and indirect traction to the miniscrew were used with derotation elastomeric chains for enhanced control of the final crown and root position (**Figs. 3 & 4a–c**). The

finishing phase was accomplished with braided multistrand stainless-steel 0.018 × 0.025 in. arch wires and intermaxillary elastics. An upper Hawley plate was used for retention after appliance removal in the maxillary arch, and a mandibular fixed retainer was bonded in the mandibular anterior segment.

Fig. 3

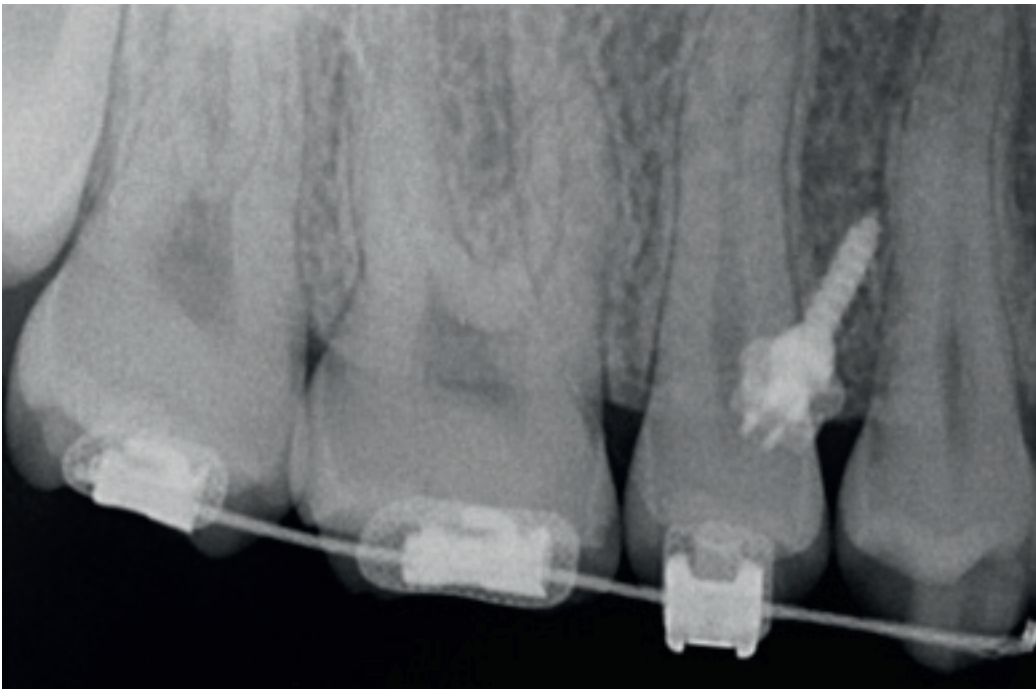


Fig. 3

Periapical radiograph showing the orthodontic miniscrew.

Figs. 4a–c

Orthodontic treatment: right (a), left (b) and occlusal (c) view.

Fig. 4a

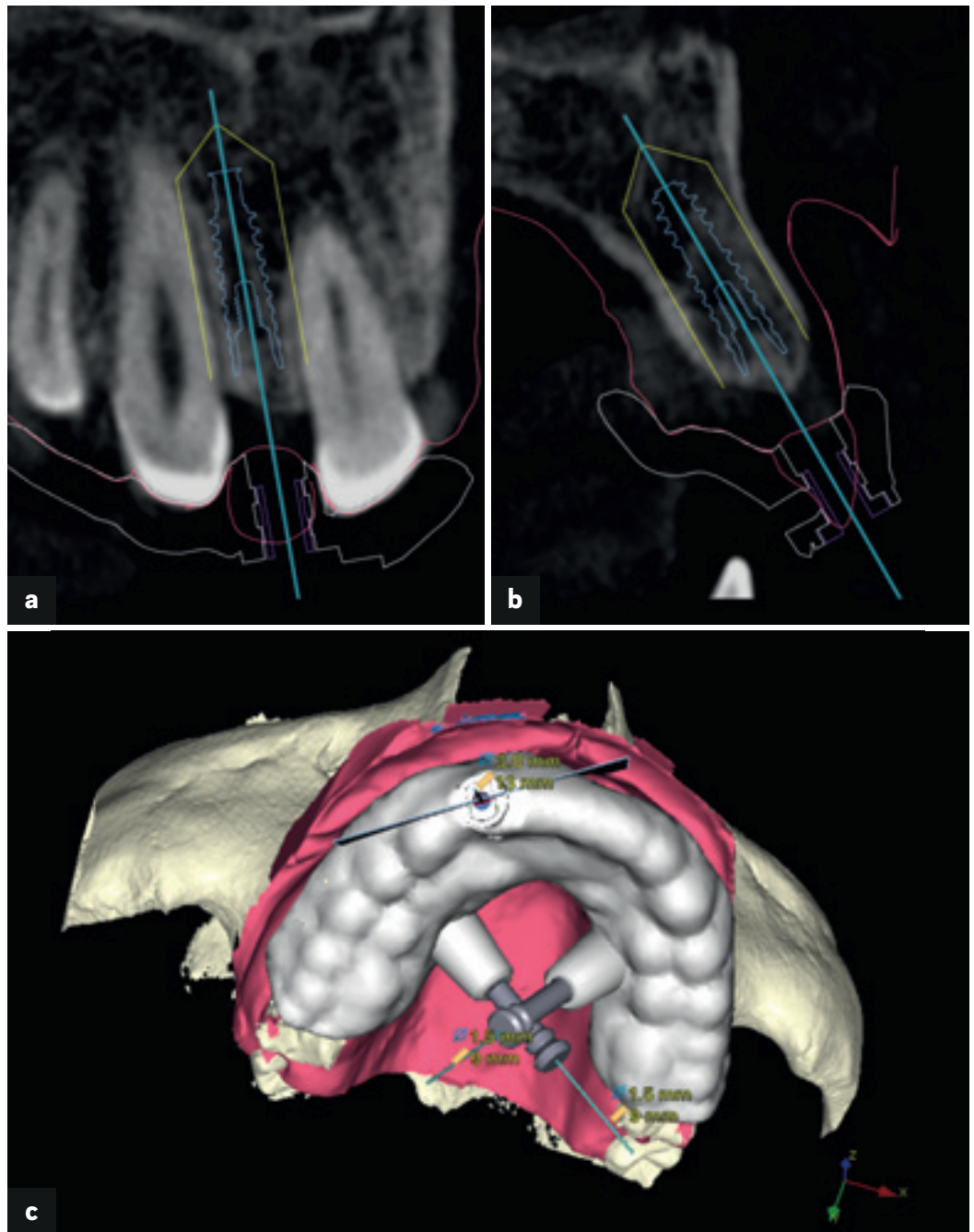


Figs. 4b & c



Figs. 5a–c

Virtual plan: frontal (a) and sagittal views (b); virtual stereolithographic surgical template (c).



Figs. 5a & b

Fig. 5c

After orthodontic treatment, the patient underwent a preoperative cone beam computed tomography (CBCT; CRANEX 3Dx, SOREDEX, Tuusula, Finland) scan, and diagnostic impressions were taken using a polyether material (Impregum, 3M ESPE, Seefeld, Germany) with a custom open tray (Diatray Top, Dental Kontor, Stockelsdorf, Germany). Furthermore, model casts were poured in Type IV stone (Techim Super Stone, Techim Group, Milan, Italy) and a diagnostic wax-up was made. The STL files derived from the scanned model and wax-up were merged with the DICOM data

derived from the CBCT scan in the same virtual implant planning software (NobelClinician, Nobel Biocare, Kloten, Switzerland). Virtual planning was completed by defining a prosthetically driven implant placement. Owing to the reduced space between adjacent roots, a 3.0 mm implant was planned (Osstem TSIII, Osstem, Seoul, South Korea). After careful functional and esthetic evaluation and final verification, the approved virtual plan was transmitted to a milling center (Nobel Biocare) for the production of a stereolithographic surgical template (**Figs. 5a–c**).

Before implant placement, the stereolithographic surgical template was adapted to the master cast. The patient underwent professional oral hygiene and received prophylactic antiseptic (0.2% chlorhexidine for 1 min) and antibiotic therapy (2 g of amoxicillin and clavulanic acid). Local anesthetic was administered with a 4% articaine solution with epinephrine 1:100 000 (Ubistein, 3M ESPE). The surgical template was placed intraorally in relation to the opposing arch using the silicone surgical index derived from the mounted casts and stabilized with two anchor pins. A flapless guided pilot drill was employed using the surgical template, and the continuity of the implant site was evaluated with the aid of a periodontal probe (PCPUNC156, Hu-Friedy, Milan, Italy). The implant was placed freehand in the planned anatomical site according to a one-stage approach, without tissue grafting. The final insertion torque was 37.5 N cm (iChiro Pro, Bien-Air Dental, Biel, Switzerland).

A new definitive impression of the maxilla was made using a polyether material (Impregum) and poured in Type IV stone (Techim Super Stone). This master cast was cross-mounted in a semi-adjustable articulator and a temporary acrylic restoration was fabricated using a temporary titanium abutment (Osstem). The temporary restoration was screwed to the implant with prosthetic screws tightened according to the manufacturer's instructions (30 N cm) 24 h after implant placement, as directed by an immediate loading protocol. The prefabricated temporary acrylic restoration was trimmed and polished chairside. A nonoccluding occlusal scheme was delivered (**Fig. 6**). After implant placement, the patient received oral and written instructions regarding medication, oral hygiene maintenance and diet. A periapical radiograph was taken with the paralleling technique in order to exclude radiolucency or other complications.

The final restoration was delivered three months after implant placement. The zirconia framework was fabricated using CAD/CAM technology (New Ancorvis, Bargellino, Italy) and veneered with ceramic. The screw-retained definitive restoration was finally attached at the torque setting recommended by the manufacturer (30 N cm; **Figs. 7 & 8**). The occlusion was carefully adjusted and the patient was recalled every 4 months for hygiene maintenance and annually for occlusal adjustment (**Figs. 9 & 10**).

Discussion

In the present report, the case was treated successfully with orthodontic space opening and prosthetic replacement of the missing lateral incisor with a single implant-supported crown. This case report aimed to describe the novel Osstem TSIII 3.0 mm (Osstem) implant used, which allows for the replacement of maxillary lateral incisors and mandibular incisors. Prompt diagnosis and an interdisciplinary approach, guided by functional and esthetic demands, are essential for the proper management of such complex cases. Teenagers with late mixed dentition or newly developed permanent dentition often seek treatment for the congenital absence of maxillary lateral incisors, because, during this period, the esthetic problem becomes more evident.

When maxillary lateral incisors are missing, there are several factors to consider before treatment with space opening or closure. These factors include the type of malocclusion, crowding/spacing, tooth size relationships, canine position, shape and color of the canines, and upper lip length.⁶⁻⁸ The choice between these two modalities of treatment should not be made empirically. In most instances, the presence or absence of major occlusal problems serves as the primary criterion for either space closure or space opening.⁹ Lateral incisal spaces should be closed in cases in which malocclusions require the extraction of permanent mandibular teeth.⁴ Mandibular extractions may be indicated to relieve anterior or posterior arch length deficiency, to reduce mandibular dentoalveolar protrusion or to compensate for a Class II molar relationship. Some orthodontic patients may be missing several permanent teeth, including maxillary lateral incisors. If teeth have been missing for several years, the remaining teeth may have drifted. In these patients, orthodontists and restorative dentists may not know what the restorative requirements are or what the eventual restorative treatment plan should be. For these types of patients, it is suggested to predetermine the final occlusal and restorative outcomes by creating diagnostic wax setups.¹⁰ In addition, the trial setup will allow identification of tooth surfaces that require functional and esthetic reduction so that equilibration may be initiated either at the beginning of or during the orthodontic treatment.

Fig. 6
Immediately loaded temporary
restoration.

Fig. 7
Definitive restoration.

Fig. 8
Periapical radiograph.

Fig. 9
Definitive restoration 1 year
after implant placement.

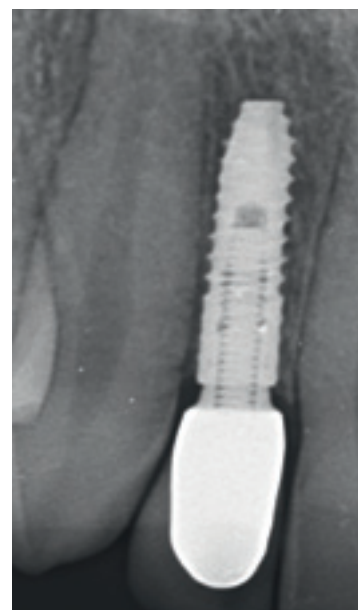
Fig. 10
Periapical radiograph 1 year
after implant placement.



Fig. 6



Figs. 7 & 8



Figs. 9 & 10

The diagnosis and treatment of growing children with missing lateral incisors can be a problem for many clinicians. If the patient and his or her parents plan on him or her undergoing implant treatment in the future, it is important that the majority of vertical facial growth and tooth eruption be completed before implant placement.⁷ After completion of growth in body height, sequential cephalometric or hand–wrist radiographs verify the cessation of facial growth over a time frame of approximately six months to one year. The sequence of treatment in cases of agenesis of anterior teeth must be carefully explained to both the patient and his or her parents. They must realize that the orthodontic treatment is the beginning of the process, which is to be followed by the scheduling of periodontal therapy and final restorations. It is crucial that all of the treatment options be discussed with the interdisciplinary team, just as all of the options are explained in the orthodontic treatment phase.

Space closure is recommended for missing lateral incisors in subjects with long faces, as it is the preferred treatment for preserving arch anchorage and avoiding clockwise rotation of the lower jaw. In addition, it is the treatment of choice in subjects with bimaxillary dental protrusion in order to avoid worsening of the profile or in cases of early treatment in adolescents. Space closure can also be considered with two types of malocclusions: a mandibular anterior with severe dental crowding and a Class I malocclusion, for which the first premolars and canines are extracted to achieve mesialization (thus obtaining a molar and canine Class I), as well as a Class II malocclusion without crowding and mandibular protrusion. Furthermore, space closure may benefit patients with a specific anterior relationship, specifically those with an increased overjet and reduced overbite. Lastly, the presence of third molars is an additional factor that would be supported by space closure mechanics. The color of the natural canine should be approximately that of the central incisor. It is not uncommon for the canine to be more saturated with color, resulting in a tooth that is one to two shades darker than the central incisor.

Space opening (between the canine and central incisor) is the second therapeutic option in the treatment of missing lateral incisors. Space opening and prosthodontic intervention are indicated in low-angle subjects and those with retruded profiles in order to improve the labial

sagittal relationship. It is also the treatment of choice in patients with molar Class I or III tendency in order to preserve an ideal occlusal anterior and posterior relationship. Space opening is also of benefit in cases with a reduced overjet and increased overbite. As mentioned previously, an important factor that clinicians should consider when deciding on treatment is the patient's age. Space opening is not recommended before the age of 13 years in order to prevent the relapse and progression of bone atrophy.¹¹ In the case of unilateral tooth agenesis, space opening is often recommended in order to improve the esthetics and preserve smile symmetry.¹²

According to Magne and Belser, there are various subjective and objective criteria for the assessment of an ideal smile.¹³ The midline is an imaginary line located at the center of the face, perpendicular to the interpupillary line. In a totally symmetrical face, the dental midline and the facial midline should coincide, but this is often not the case.¹⁴ According to Spear et al., a midline deviation greater than 4 mm can be detected by the general public,¹⁵ whereas a midline deviation of 2 mm remains undetectable by laypersons.¹⁴

Given these considerations, the choice of opening space for the implant in our patient was especially influenced by the presence of microdontia of the maxillary left lateral incisor and the midline deviation of over 3 mm.

When examining the esthetics of the anterior teeth and overall smile, the clinician should be aware of the morphology of the gingival contours, tooth contacts, tooth morphology and tooth size problems. In order to obtain ideal esthetic results, worn incisal edges, tooth shape, incisal contact, the contours of the gingival margins, and black triangles should be considered before starting orthodontic treatment. The decision to reshape or add tooth structure should be evaluated in light of the width-to-length ratios of the golden proportion.¹⁶ It appears clinically that long, tapered triangular maxillary incisors have thin, arched gingival tissue with a longer, delicate papilla and thin bone with a smaller incisal contact point. In contrast, rectangular-shaped incisors tend to have thicker gingiva with a flatter, wider free gingival margin. Furthermore, these latter teeth have broad contacts. Generally speaking, the more rectangular the teeth, the thicker the alveolus and the gingiva that house them.¹⁷

Present-day demands and expectations of esthetic dentistry are growing. In order to pro-

vide esthetic anterior tooth shape and correct agenesis, patients must be informed of their total dental needs, not just those associated with a limited specialty. In order to integrate and coordinate treatment, patients need to be offered a total treatment approach that maximizes function, esthetics and oral health. In many common dental malocclusions, orthodontic treatment alone may not be enough.¹⁸

Computer-assisted, template-based implant placement may help clinicians to perform successful implant therapy, avoiding elevation of large flaps or even eliminating flaps completely and thereby causing less pain and discomfort to patients, particularly in complex cases.^{19–22} Correct estimation of the bone condition and the implant position and precise drilling into the bone according to the preoperative planning may be essential in ensuring the successful placement of an implant.

Conclusion

Comprehensive interdisciplinary rehabilitation according to the CRANIO philosophy was effective in successfully restoring function and esthetics in a young female patient affected by congenitally missing maxillary lateral incisor.

Competing interests

The first author (MT) is the Research and Scientific Project Manager at Osstem AIC, Italy. Osstem, Seoul, South Korea, the manufacturer of the implant system evaluated in this investigation, kindly donated the implant placed. However, the data remained that of the authors and in no manner did the manufacturer interfere with the conduct of the trial or the publication of the results.

References

- Kiliaridis S, Sidira M, Kirmanidou Y, Michalakakis K. Treatment options for congenitally missing lateral incisors. → Eur J Oral Implantol. 2016;9 Suppl 1:S5–24.
- Muller TP, Hill IN, Peterson AC, Blayney JR. A survey of congenitally missing permanent teeth. → J Am Dent Assoc. 1970 Jul;81(1):101–7.
- Stamatiou J, Symons AL. Agensis of the permanent lateral incisor: distribution, number and sites. → J Clin Pediatr Dent. 1991 Summer;15(4):244–6.
- Andrade DC, Loureiro CA, Araújo VE, Riera R, Atallah AN. Treatment for agenesis of maxillary lateral incisors: a systematic review. → Orthod Craniofac Res. 2013 Aug;16(3):129–36.
- Silveira GS, Mucha JN. Agensis of maxillary lateral incisors: treatment involves much more than just canine guidance. → Open Dent J. 2016 Feb;10:19–27.
- Thordarson A, Zachrisson BU, Mjor IA. Remodeling of canines to the shape of lateral incisors by grinding: a long-term clinical and radiographic evaluation. → Am J Orthod Dentofacial Orthop. 1991 Aug;100(2):123–32.
- Kokich VO Jr. Congenitally missing teeth: orthodontic management in the adolescent patient. → Am J Orthod Dentofacial Orthop. 2002 Jun;121(6):594–5.
- Robertsson S, Mohlin B. The congenital missing upper lateral incisor. A retrospective study of orthodontic space closure versus restorative treatment. → Eur J Orthod. 2000 Dec;22(6):697–710.
- Zachrisson BU. Improving orthodontic results in cases with maxillary incisors missing. → Am J Orthod. 1978 Mar;73(3):274–89.
- Kokich VG, Spear FM. Guidelines of managing the orthodontic-restorative patient. → Semin Orthod. 1997 Mar;3(1):3–20.
- Beyer A, Tausche E, Boening K, Harzer W. Orthodontic space opening in patients with congenitally missing lateral incisors. → Angle Orthod. 2007 May;77(3):404–9.
- Rosa M, Zachrisson BU. The space-closure alternative for missing maxillary lateral incisors: an update. → J Clin Orthod. 2010 Sep;44(9):540–9; quiz 561.
- Magne P, Belser U. Bonded porcelain restorations in the anterior dentition: a biomimetic approach. → Chicago: Quintessence. 2002. 406 p.
- Pinho S, Ciriaco C, Faber J, Lenza MA. Impact of dental asymmetries on the perception of smile esthetics. → Am J Orthod Dentofacial Orthop. 2007 Dec;132(6):748–53.
- Spear FM, Kokich VG, Mathews DP. Interdisciplinary management of anterior dental aesthetics. → J Am Dent Assoc. 2006 Feb;137(2):160–9.
- Ricketts RM. The biologic significance of the divine proportion and Fibonacci series. → Am J Orthod. 1982 May;81(5):351–70.
- Morley J, Eubank J. Macroesthetic elements of smile design. → J Am Dent Assoc. 2001 Jan;132(1):39–45.
- Kavadia S, Papadiochou S, Papadiochos I, Zafiriadis L. Agensis of maxillary lateral incisors: a global overview of the clinical problem. → Orthodontics (Chic.). 2011 Winter;12(4):296–317.
- Tallarico M, Meloni SM, Canullo L, Polizzi G. Guided surgery for single-implant placement: a critical review. → J Oral Science Rehabilitation. 2016 Dec;2(4):8–14.
- Tallarico M, Meloni SM, Canullo L, Caneva M, Polizzi G. Five-year results of a randomized controlled trial comparing patients rehabilitated with immediately loaded maxillary cross-arch fixed dental prosthesis supported by four or six implants placed using guided surgery. → Clin Implant Dent Relat Res. 2016 Oct;18(5):965–72. doi:10.1111/cid.12380. Epub 2015 Oct 7.
- Pozzi A, Tallarico M, Marchetti M, Scarfo B, Esposito M. Computer-guided versus free-hand placement of immediately loaded dental implants: 1-year post-loading results of a multicentre randomised controlled trial. → Eur J Oral Implantol. 2014 Autumn;7(3):229–42.
- Pozzi A, Tallarico M, Mangani F, Barlattani A. Different implant impression techniques for edentulous patients treated with CAD/CAM complete-arch prostheses: a randomised controlled trial reporting data at 3 year post-loading. → Eur J Oral Implantol. 2013 Winter;6(4):325–40.

www.dds.world

JOIN NOW!

**THE MOST
COMPREHENSIVE
RESOURCE
IN DENTISTRY**

*Registration is free until 31 August 2017.

Biological and physical properties of bone block grafting biomaterials for alveolar ridge augmentation

Alberto Monje^a & Hom-Lay Wang^a

^a Graduate Periodontics, Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, Mich., U.S.

Corresponding author:

Dr. Alberto Monje and Prof. Hom-Lay Wang

Department of Periodontics and Oral Medicine
School of Dentistry
University of Michigan
1011 North University Ave.
Ann Arbor, MI 48109-1078
U.S.

T +1 734 763 3383
amonjec@umich.edu
homlay@umich.edu

How to cite this article:

Monje A, Wang HL. Biological and physical properties of bone block substitute biomaterials for ridge augmentation. *J Oral Science Rehabilitation*. 2017 Mar;3(1):18–30.

Abstract

Objective

Bone resorption of maxillary ridges is an unavoidable process that occurs after tooth extraction. Many treatment alternatives have been proposed to facilitate implant placement in these scenarios. Drawbacks such as morbidity, cost and excessive resorption owing to the procedure have prompted clinicians to seek biomaterials as an alternative to autogenous bone. The objective of this article was to review the current state of the art by means of the biological and physical properties of biomaterials used for block grafting in atrophic maxillary ridges. Secondly, it was aimed herein at presenting the clinical and histological findings when using these biomaterials.

Materials and methods

An electronic and manual literature search was conducted by two independent reviewers using several databases, including MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials and Cochrane Oral Health Group Trials Register databases, for articles written in English up to June 2016. Owing to the heterogeneity of the findings, quantitative assessment could not be conducted. As such, a narrative review was carried out on the biological and physical aspects of biomaterials used for block grafting.

Results

Both allogeneic and xenogeneic block grafts have been developed to overcome deficiencies of autogenous grafts. Allogeneic block grafts have been widely investigated, but there is a lack of long-term follow-up. On the contrary, xenogeneic block grafts have only limited scientific evidence of their suitability for ridge reconstruction.

Conclusion

Allogeneic and xenogeneic bone block grafts represent a promising alternative to autogenous bone for ridge augmentation. Nonetheless, the evidence supporting xenogeneic block graft usage remains minimal; hence, more long-term human studies are needed to validate their effectiveness. In addition, using prefabricated scaffolds impregnated with growth factors provides an interesting field to be further explored.

Keywords

Bone grafting, bone biomaterials, allogeneic, xenogeneic, bone substitutes.

Introduction

After tooth extraction, bone remodeling that leads to bone resorption is a common phenomenon. Ridge resorption has made grafting procedures popular in implant and restorative therapy.¹⁻⁴ These procedures aim at restoring width and height for proper 3-D implant placement. Numerous treatment alternatives have been proposed (e.g., distraction osteogenesis and guided bone regeneration with particulated bone materials).⁵ Nonetheless, for extensive or severely atrophic ridges, block grafting has been advocated to be the most predictable approach.^{6,7}

Autogenous bone has been regarded as the gold standard for bone reconstruction.⁸ This can be harvested from different locations based upon the extension of the atrophic area.⁸ While intraoral bone block grafts (mandibular ramus or mental symphysis) can be harvested with a less traumatic approach, the amount is often limited. However, extraoral bone block grafts (calvaria or iliac crest) fulfill the requirements in terms of quantity, but they increase the cost and lead to some sequelae for the donor site. Regardless of the harvesting location, autogenous block grafts might be further classified depending on their origin. For example, intra-membranous grafts (mandibular ramus and calvaria bone) have less bone resorption and the process of bone remodeling or "creeping substitution" takes longer⁹ compared with endochondral bone (iliac crest).¹⁰ Hence, it is important to take this into consideration when planning implant treatment so that it will not cause extensive bone remodeling that threatens the final adequate prosthetically driven implant position.^{11,12}

Indeed, autologous bone has osteogenic capacity;⁸ in other words, bone can potentially grow in between the interface of the graft and the host bone. Nevertheless, as already mentioned, the drawbacks associated with this approach have encouraged clinicians to use alternatives, such as allogeneic or xenogeneic bone blocks.^{13,14} These treatment modalities not only reduce the possibility of experiencing morbidity, but also shorten the treatment and, hence, increase patient acceptance and satisfaction. The mechanism of forming new mineralized tissue is mediated by the mesenchymal cells, which differentiate into osteoblasts that are coordinated by glycoproteins (bone morphogenetic proteins).¹⁵ Hence, after an inflammatory

process that ends in gradual substitution, the newly formed bone is obtained,¹⁶ or in this case hard tissue capable of obtaining first implant stability and subsequently osseointegration.

In general, allogeneic and xenogeneic block grafts do not contain osteoprogenitor cells and, consequently, integration with the native bone might be arduous. Promising results have been shown in the literature with application of these block grafts for bone regeneration.^{17,18} Depending on their origin, they can be either from human (cadaver), known also as allografts, or from animal origin (equine and bovine), which are also called xenografts. Once harvested, the grafts must be preserved, and each manufacturing company has developed its own process that can potentially determine the properties of the respective biomaterial.

The objective of this article was to review the biological and physical properties of block grafting biomaterials available for bone regeneration in atrophic maxillary ridges. Furthermore, the aim was to present the human and animal clinical and histological findings of biomaterials used for maxillary reconstructions.

Materials and methods

Information sources

An electronic literature search was conducted by two independent reviewers (AM and HLW) of several databases, including MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials and Cochrane Oral Health Group Trials Register databases, for articles written in English up to June 2016.

Screening process

Combinations of controlled terms (MeSH and Emtree) and keywords were used whenever possible:

```
(((((Alveolar bone atrophy[MeSH Terms])
OR alveolar bone loss[MeSH Terms])
AND bone grafting[MeSH Terms])
OR allograft[MeSH Terms])
OR xenograft[MeSH Terms])
OR biomaterials[MeSH Terms])
AND block)
OR onlay
OR
```


(((((("alveolar bone loss"[MeSH Terms]
OR "alveolar bone loss"[MeSH Terms])
AND bone graft[Title/Abstract])
AND block[Title/Abstract])
OR onlay[Title/Abstract])
AND biomaterial[Title/Abstract])
OR allogeneic[Title/Abstract])
OR allograft[Title/Abstract])
OR xenogeneic[Title/Abstract])
OR xenograft[Title/Abstract]
AND "humans"[MeSH Terms]

Additionally, a manual search of periodontics- and implantology-related journals, including the *Journal of Dental Research*, *Journal of Clinical Periodontology*, *Journal of Periodontology*, and *International Journal of Periodontics and Restorative Dentistry*, from January 2015 up to June 2016, was performed to ensure a thorough screening process. Furthermore, references of included articles were screened to check all available articles.

Biomaterials' properties

"Biomaterial" refers, generally speaking, to material that has been developed to interact with the biological system, acting as a scaffold for replacement and repair of, in this case, lost bone. Firstly, a biomaterial must be biocompatible, which is defined as the capacity that the material has to elicit an appropriate biological response and, thus, not be detected as a foreign body by the host. In addition, it must have sufficient durability to carry out the task for which it was developed. Further, it must be chemically stable (neither toxic nor carcinogenic for the host).

For block grafts used in regeneration, an ideal biomaterial, from the cellular and molecular standpoint, must have the following properties:

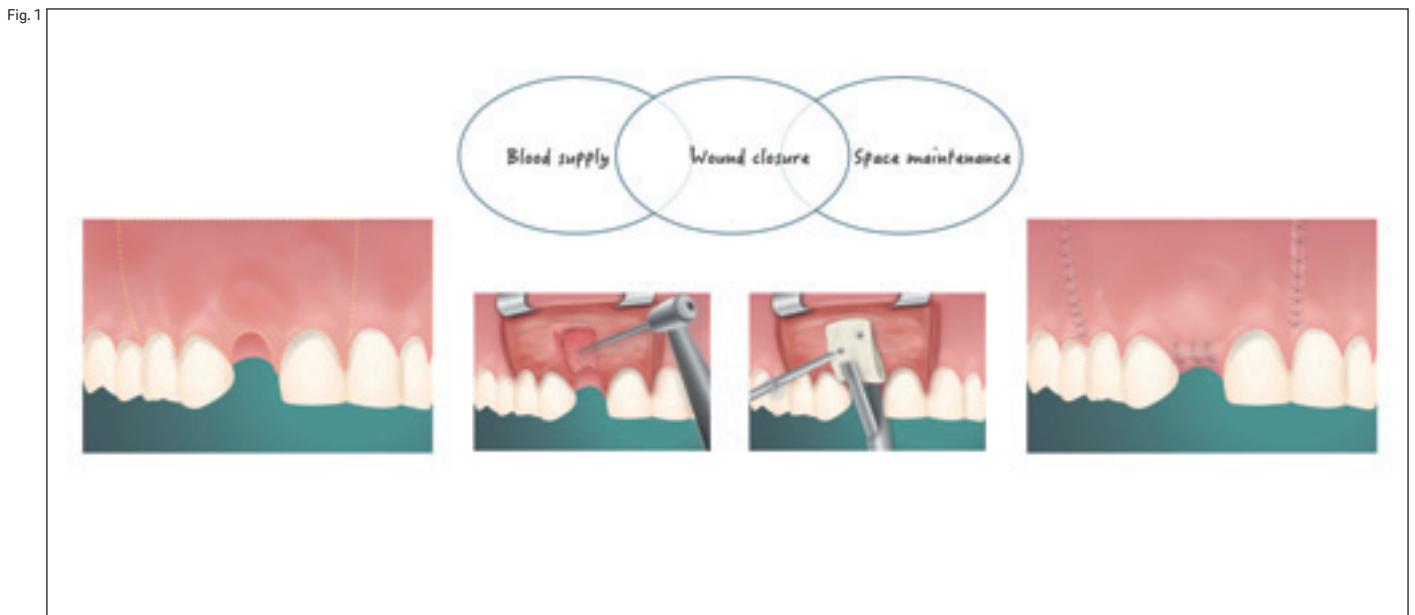
- Its design enables osteogenic cells to reach the entire block by osteoconduction and osteoinduction in order to complete the turnover process. In order to permit osteoblastic growth and mineralized tissue production, the ideal size of the micropores should be within 180–600 μ .¹⁹ This is of crucial importance inasmuch as osteoblasts (15–50 μ) and stem cells (5–12 μ) have to proliferate guided through the pores.²⁰ The biomaterial itself must be replaced by vital bone (newly formed bone). Therefore, the biomaterial's degradation must be in accordance with the remodeling process.

- The trabeculae-like structures that form the scaffold must leave enough space for the formation of new vessels by the endothelial cells that will supply of all the nutrients and osseous cells to the scaffold.

Therefore, as occurs in autogenous bone blocks, biomaterials undergo three steps: (1) colonization of host cells; (2) degradation of the biomaterial while turnover is occurring; and (3) maturation of the newly formed bone and integration with the recipient site's bone (Fig. 1).

However, biomaterials in bone grafting must fulfill other properties besides biological ones. This will allow the material to interact with the host environment and, thus, increase the possibility of bone formation and long-term stability. These properties should include:

- Mechanical properties: Among these properties are resistance, resilience, stiffness, fragility, tenacity, ductility and malleability. The result of the combination of these mechanical properties will determine the handling of the material more than its capacity as scaffold for bone regeneration.²¹ However, it is important to note that, generally, the stiffer the biomaterial is, the longer it lasts due to the more rigid element.
- Surface phenomena: It is important to take into consideration the internal energy, surface tension, wettability, and adhesion and cohesion of the biomaterial to be used for bone regeneration. These properties are in part responsible for the aggregation and attachment of vital osteogenic cells in a nonvital structure (scaffold).²¹
- Physical properties: Three main properties are included within this group:
 - Thermals: thermal expansion, thermal contraction, thermal insulation, melting point and interval;
 - Electrics: electric conductivity, electrical resistivity and oral galvanism; and
 - Optics: color and appearance.
- Chemical properties: toxicity, chemical stability, half-life, flammability or enthalpy of formation among others.
- Rheological properties: apparent viscosity, normal force coefficients, storage modulus, complex viscosity and complex functions of nonlinear viscoelasticity.

**Fig. 1**

Descriptive illustration of the onlay bone grafting procedure. In order to be successful, the three elements must be achieved to ensure a proper creeping substitution process.

Vascularization

Biomaterials used in bone regeneration lack cells, proteins and vessels. In this manner, risk of disease transmission is minimized. Therefore, cells from the recipient site of the graft carry out the process of neoangiogenesis, an essential step for successful bone regeneration.²² Neo-vascularization indeed is fundamental because it supplies the avascular scaffold with oxygen and the nutrients required for cell growth and differentiation.²³ Accordingly, newly formed bone and resorption of the block graft rely upon the neoangiogenesis process. Numerous growth factors, such as vascular endothelial growth factor (VEGF), fibroblast growth factor (FGF), some subgroups of the transforming growth factor beta family (TGF- β), transcription factor to induce hypoxia (HIF), angiopoietin (Ang-1), hepatocyte growth factor (HGF), platelet-derived growth factor (PDGF-BB), insulin-like derived growth factor (IGF-1, IGF-2) and neurotrophic growth factor (NGF) are involved in the process.²⁴ Accordingly, VEGFs and their receptors are in charge of the molecular and cellular cascade inasmuch as they lead the development of the endothelial system by vasculogenesis, angiogenesis and the lymphatic net. Additionally, VEGFs play a meaningful role in skeletal growth and in bone repair and regeneration.²⁵ Likewise, FGFs are in charge of promoting proliferation and differentiation of endothelial cells and fibroblasts. On the contrary, TGFs increase

extracellular matrix development. HIFs mediate the effects of hypoxia on the cells. Ang-1 stabilizes the vessels. However, HGFs act on epithelial and endothelial cells for organ regeneration and wound healing. Commonly used as exogenous growth factors in bone regeneration, the PDGF family plays an important role in angiogenesis. IGFs in contrast have endocrine effects upon the host. Lastly, NGFs, also known as neurotrophins, maintain nerve cells within the horizontal newly formed bone.^{26, 27}

In bone regeneration using block grafts as scaffolds, new tendencies are arising, since, contrary to autogenous grafts, early neoangiogenesis is essential for biomaterial survival and integration. In consequence, techniques such as the delivery of stem cells and growth factors in order to accelerate the process have been closely examined recently with promising results.²⁸ However, there is still a lack of results to make any conclusive statement in this regard.

Types of block graft biomaterials

1. Allogeneic block grafts

The use of allografts represents a fair alternative to autogenous block grafts, since the blocks are harvested from the same species as that of the recipient. The first bone allografts were performed in late 19th century by a group of surgeons who reconstructed an infected humerus with a graft harvested from the tibia of the same

patient.²⁹ The establishment of the U.S. Navy Tissue Bank in 1990 was a significant influencing factor for the wide use of bone allografts. The use of allografts has continued to increase since then.³⁰

Properties

The properties of allograft material are directly related to its processing and its precedence.³¹ Allogeneic block grafts may be prepared as fresh, frozen and freeze-dried. Nowadays, the vast majority of grafts are carefully screened, harvested, processed and distributed, and this is governed by the American Association of Tissue Banks. The risk of disease transmission is often minimized through the above processes.^{32,33} In addition, during graft preparation, the antigenic components are carefully removed to eliminate any potential host immune response.³²

Fresh or frozen allografts retain both osteoinductive and osteoconductive capacities, allowing a slightly faster bone turnover than that of freeze-dried allografts. However, the risks of disease transmission and host reactions are slightly increased,³⁴ whereas the immune response is reduced in freeze-dried allografts.³⁴ This is due to the elimination of the cells by embedding the graft in antibiotic wash twice for 1 h and then storing it at -70 °C to dry up to 5% of the water.^{35,36} Another issue to bear in mind is that, because of the drying, mechanical properties are weakened. Hence, microfracture of the grafts might easily occur. Consequently, for this type of block allograft, rehydration is suggested prior to placement in order to regain some of the mechanical properties.³⁷ Currently, Zimmer Biomet Dental (Carlsbad, Calif., U.S.) has patented its suitable preparation sequence (**Fig. 2**). This is the Tutoplast process, which includes cleaning and ultrasonic lipidization in acetone, an osmotic and later oxidative treatment, ending with dehydration in sequential acetone baths and gamma irradiation.³⁸ The result of this process is a greater preservation of the minerals and collagen matrix, leading to rapid bone turnover.³⁹

Clinical outcomes

Bone block allografts are a relatively novel alternative to autogenous grafts for horizontal and/or vertical bone augmentation of the atrophic maxilla (**Table 1**). In 1999, the first case of using an allogeneic block bone graft for bone regeneration was reported. In that case, dental implants for oral rehabilitation were successful-

ly placed three months after the grafting procedure.¹⁸ Since then, multiple prospective human clinical trials have been published demonstrating proof of principle for this human allograft block usage.^{40–56}

From our clinical experience and others', when the human allograft is exposed to the oral cavity, it often leads to graft failure.^{42,57} Moreover, it has much higher failure rate in the mandible than in the maxilla owing to difficulty in flap advancement and a thinner soft-tissue biotype.⁵⁸ Failure of a block graft generally occurs in the early stages of graft healing.^{41,45,52,55} In addition, bone graft resorption occurs during healing, which is the same as with autogenous grafts. However, greater bone loss occurs at six months after placement compared with autogenous bone harvested from the mandibular ramus ($52.00 \pm 25.87\%$ vs. $25.00 \pm 12.73\%$, respectively).⁴⁶ A recent systematic review found promising results on the use of allogeneic bone grafts for horizontal bone augmentation in maxillae.⁵⁹ It was shown that not only high graft and implant survival rates had been achieved (98.0% and 96.9%, respectively), but also that a weighed mean of 4.79 mm of horizontal bone had been gained over a mean follow-up period of 23.9 months.

Histological and histomorphometric outcomes

Indeed, allogeneic block grafts do not behave like autogenous bone from the cellular standpoint because of the lack of osteogenic potential; notwithstanding, respecting a proper healing time (more than six months), this biomaterial results in similar clinical healing to that of native bone^{40–56} (**Figs. 3a–c & 4**). Acocella et al. showed that, after nine months, a high number of empty osteocyte lacunae were still present and that more fibrous tissue was present than in the samples taken previously.⁴⁰ Additionally, newly formed bone ($61.96 \pm 11.77\%$) was surrounded by nonvital bone with empty osteocyte lacunae. At the same time after healing, Contar et al. demonstrated a lamellar arrangement around Haversian canals interspersed with osteocytes in lacunae.⁴³ They also observed that the central portions of the grafts showed osteocytes with a higher number of empty lacunae.

When histological results are compared between groups (allogeneic vs. autogenous), behavioral dissimilarities are displayed. Lumetti et al. showed that, after six months of healing, osteocyte lacunae were mostly empty for the

Fig. 2

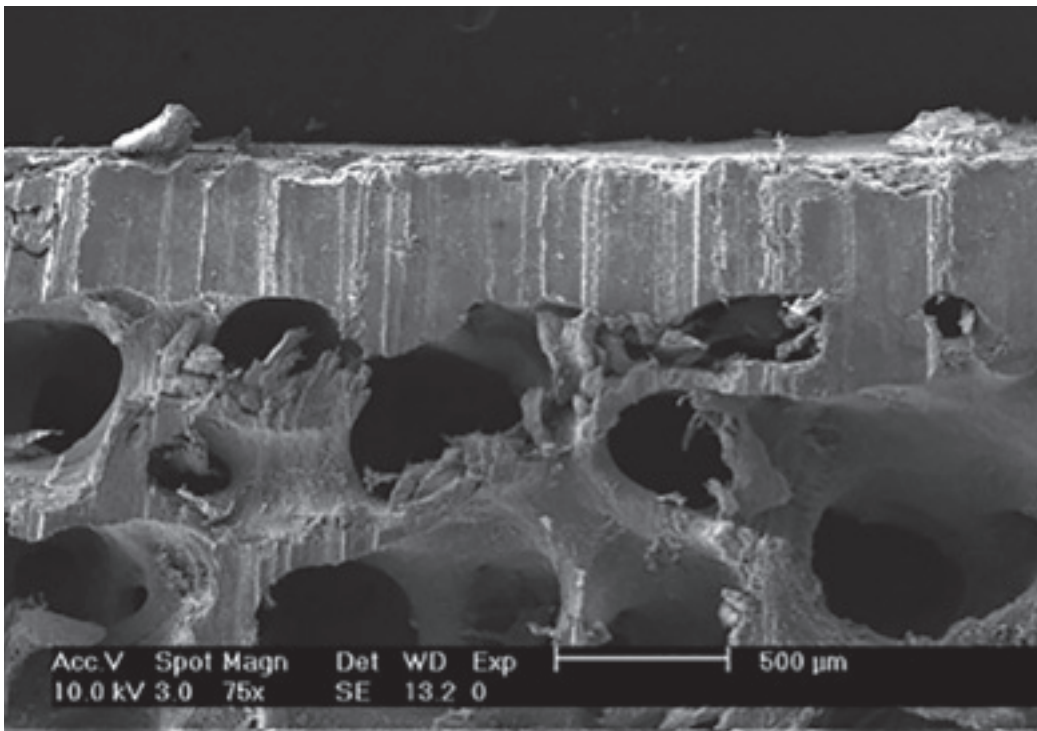


Fig. 2

Scanning electron microscopy image of the Puros Block Allograft (Zimmer Biomet Dental) microarchitecture (75× magnification). (Courtesy of Zimmer Dental).

Figs. 3a–c

Histological samples of Puros Block Allograft six months after a regenerative procedure of the atrophic maxillae (100× magnification [a] and 400× magnification [b & c]).

Fig. 4

Histological sample of J-Block Puros Allograft six months after a regenerative procedure for horizontal augmentation in atrophic maxillae. Note the high amount of newly formed bone present, while the percentage of remaining material is decreased.

Figs. 3a–c

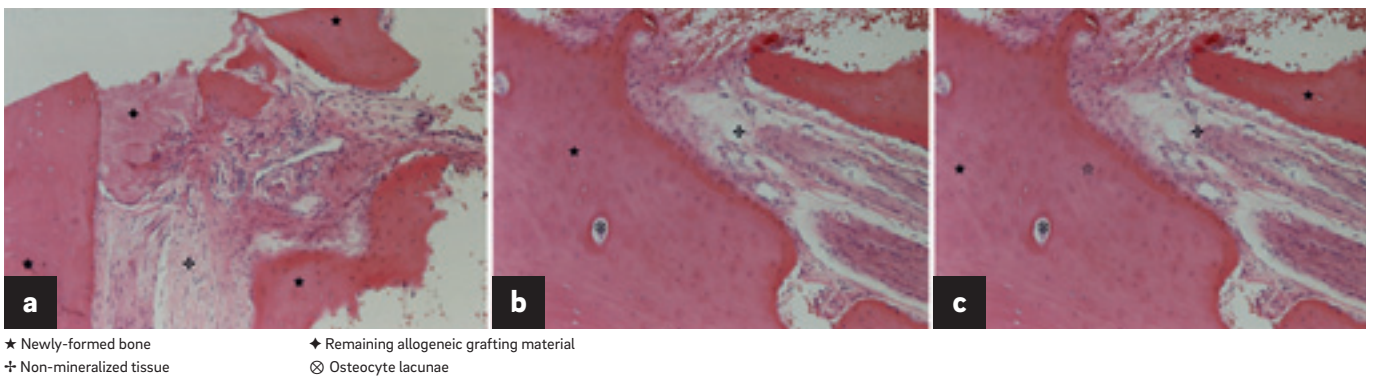


Fig. 4



Author (year)	Study design	Groups	No. of patients	No. of sites grafted	Location of grafted sites	Bone augmentation (V/H)	Type of bone block graft	
Acocella et al. (2012) ⁴⁰	Prospective case series	NCG	16	18	Anterior/posterior	H	Monocortical fresh-frozen	
Barone et al. (2009) ⁴¹	Prospective case series	NCG	13	24	Anterior (13)/ posterior (9)	H (19)/V (5)	Corticocancellous deep-frozen	
Chausu et al. (2010) ⁴²	Prospective case series	NCG	101	90	Anterior (58)/ posterior (32)	NC	Cancellous fresh-frozen	
Contar et al. (2009) ⁴⁴	Prospective case series	NCG	15	34	Anterior/posterior	H	Cancellous/cortical fresh-frozen	
Contar et al. (2011) ⁴³	Prospective case series	NCG	18	39	Anterior/posterior	NC	Cancellous/cortical fresh-frozen	
							Cortical fresh-frozen	
Wallace & Gellin (2010) ⁵⁶	Prospective case series	NCG	12	16	Anterior/posterior	H	Cancellous fresh-frozen	
Spin-Neto et al. (2013)	Prospective case series	AL	13	17	Anterior (14)/posterior (3)	H	Corticocancellous deep-frozen	
		AT	13	17			Mandibular ramus	
Novell et al. (2012) ⁵²	Prospective case series	NCG	12	20	Anterior/posterior	H/H + V	Cortical/cancellous fresh-frozen	
Deluiz et al. (2013) ⁴⁵	Prospective case series	NCG	24	24	Anterior/posterior	H	Corticocancellous fresh-frozen	
Nissan et al. (2011) ⁵¹	Prospective case series	NCG	20	28	Anterior	H (27)/V (12)	Cancellous fresh-frozen	
Nissan et al. (2011) ⁵¹	Prospective case series	NCG	31	46	Anterior	H (42)/V (27)	Cancellous fresh-frozen	
Nissan et al. (2008) ⁵⁰	Prospective case series	NCG	11	11	Anterior	H/V	Cancellous fresh-frozen	
Lumetti et al. (2012) ⁴⁶	RCT	AL	12	12	Anterior/posterior	H	Corticocancellous fresh-frozen	
		AT	12	12			Mandibular ramus	
Spin-Neto et al. (2013) ⁵⁵	Prospective case series	AL	6	17	Anterior/posterior	H	Cortical fresh-frozen	
		AT	6	12			Mandibular ramus	
Peleg et al. (2010) ⁵³	Prospective case series	NCG	34	38	Anterior (31)/ posterior (7)	H/H + V	Corticocancellous fresh-frozen	

RCT = randomized controlled trial; AL = allogeneic graft; AT = autogenous graft; H = horizontal; V = vertical; Y = yes; N = no; MCA = mineralized cortical allograft; BBM = bovine bone mineral; NC = not clear; NM = not mentioned; NCG = no control group.

Table 1

	Membrane (Y/N)	Additional grafting material/growth factor	Healing period (months)	Resorption (%)	Histological analysis	
					Newly formed bone (%)	Characteristics
	N	N	9	11.45 ± 8.37	61.96 ± 11.77	A high number of empty osteocyte lacunae were still present and more fibrous tissue was present than in the samples taken previously. Newly formed bone was surrounded by nonvital bone with empty osteocyte lacunae.
	N	Cancellous allograft particles	5	NM	NM	NM
	Y	N	6	NM	NM	NM
	N	N	NC	NM	NM	Mature and compact osseous tissue surrounded by marrow spaces
	N	N	9	NM	NM	Lamellar arrangement around Haversian canals interspersed with osteocytes in lacunae. No evidence of inflammatory infiltrate. The central portions revealed osteocytes with a higher number of empty lacunae.
	Y	MCA + rhPDGF-BB	5	NM	NM	NM
	Y	N	6	NC	NM	NM
	Y	Freeze-dried allograft particles	NM	NM	NM	NM
	N		8	13.02 ± 3.86	NM	Newly formed bone with osteocytes was observed at all of the time points. Osteocyte presence was higher at 4 months. Vessels were also detected abundantly in the samples.
	Y	Particulate BBM	6	NM	NM	NM
	Y	Particulate BBM	6	10.00 ± 1.00	NM	NM
	Y	Particulate BBM	6	NM	NM	NM
	Y	Particulate fresh-frozen	6	52.00 ± 25.87	NC	Osteocyte lacunae were mostly empty. Newly formed bone contained viable osteocytes. Bone-forming osteoblasts and fluorescent labeling were detected. Dense connective tissue with the presence of inflammatory cells (WM score = 1.67) and eroded areas.
				25.00 ± 12.73	NC	Osteocyte lacunae were mostly empty. Newly formed bone contained viable osteocytes. Bone-forming osteoblasts and fluorescent labeling were detected. WM inflammatory score = 1.
	Y	N	7	NM	NM	Large segments of necrotic bone with empty osteocyte lacunae and little osteoclastic activity. Blood vessels were invading the Haversian canals of the material. No direct contact was found between remodeled and grafted bone. Some osteoclastic activity surrounded by connective tissue with no presence of inflammatory cells by newly formed bone failed to invade the graft.
				NM	NM	Small areas of necrotic bone with abundant presence of osteocytes. No difference between the grafted and the host bone.
	Y	N	4	NM	NM	NM

Table 1

Studies demonstrating the clinical and histological characteristics of the prospective (cohort and case series) testing of allograft block grafts for horizontal and /or vertical bone augmentation of the atrophic maxilla.

allogeneic block graft group⁴⁶ and that newly formed bone contained viable osteocytes. In these samples, bone-forming osteoblasts were detected. Dense connective tissue with the presence of inflammatory cells and eroded areas were also reported. Minimal differences were shown for the autogenous block graft group, in which no connective tissue was found and the presence of inflammatory cells was low. However, Spin-Neto et al. found major differences between groups.⁵⁵ The following histological characteristics were found to be associated with allogeneic bone block grafts: (a) large segments of necrotic bone with empty osteocyte lacunae and little osteoclastic activity; (b) blood vessels invading the Haversian canals of the material—no direct contact was found between remodeled and grafted bone; and (c) some osteoclastic activity surrounded by connective tissue with no presence of inflammatory cells by newly formed bone failed to invade the graft. On the contrary, autogenous block grafts presented small areas of necrotic bone with a higher number of osteocytes and a smoother junction between the graft and host bed. Therefore, from the cellular standpoint, allogeneic block grafts in the early stages of healing behave in a different manner to autogenous block grafts. However, the long-term outcome and differences remain to be determined.

2. Xenogeneic block grafts

Xenografts, which are derived from a genetically different species than the host, represent another potential alternative to autogenous block grafts for bone augmentation. Similar to human allografts, the lack of osteogenic capacity makes them less predictable in terms of graft incorporation into host bone. In addition, lack of human cells turns xenografts into scaffolds with no osteoinductive potential. Despite its novel applicability as block grafts for augmenting severely atrophied bone, this type of biomaterial has been widely used as particulate bone graft, showing excellent outcomes by means of space maintenance.^{60–62} Thus far, there is a scarcity of literature regarding this biomaterial for onlay grafts, and xenogeneic block grafts have been used more commonly as inlay grafts. As mentioned above, vascularity for this biomaterial is even more critical for success and, consequently, a three-wall defect (as displayed by host bone for inlay grafts) often makes this approach more reliable. However, an advantage of using xeno-

geneic biomaterial is that, owing to its slow rate of resorption, space is better maintained over the long term (**Fig. 5**).^{63,64}

Currently, two types of xenografts are available as blocks for bone augmentation: bovine and equine. While deproteinized bovine bone relies on its acceptability by clinicians, equine bone has shown to be less fragile to fracture.⁶⁵ However, as mentioned, more studies are needed to verify the viability of this type of biomaterial in comparison to autogenous or allogeneic block grafts.

Properties

In contrast to human-derived bone, xenogeneic grafts do not have osteoinductive potential. Therefore, they are used only as scaffolds for space maintenance and cell migration guidance. Geistlich Bio-Oss (Geistlich Pharma, Wolhusen, Switzerland), a bovine-derived biomaterial, is the most widely used xenogeneic graft. This biomaterial is claimed to have all organic material removed, so is nonantigenic. A modified Geistlich Bio-Oss block that contains more collagen components for improving its manageability has also been introduced.⁶⁶ Equine bone blocks have recently been introduced and have shown to provide an improved scaffold for cases of severe atrophy owing to this bone's natural trabecular structure.⁶⁷

Xenogeneic biomaterials, albeit not posing osteoinductive potential, are claimed to serve as slow-resorption scaffolds capable of promoting bone formation.^{68,69} Nonetheless, more studies on this material are still needed to better understand its overall properties and long-term results.

Clinical outcomes

As mentioned before, studies on xenogeneic block grafts are limited.⁸ At this point, only a few *in vivo* studies have been carried out on this biomaterial.^{66,67,70–72} The xenogeneic block graft has been advocated for bone augmentation. Steigmann presented the first human case report that used this biomaterial for horizontal bone augmentation in the maxillary anterior region.⁸⁵ Li et al. successfully used Geistlich Bio-Oss blocks for horizontal bone augmentation via a subperiosteal tunneling approach.⁷⁰ This might represent an alternative approach for placing this specific biomaterial owing to the success rate it achieved. Despite these preliminary results, we still need more evidence to support the use of xenogeneic materials for onlay block grafting.

Fig. 5

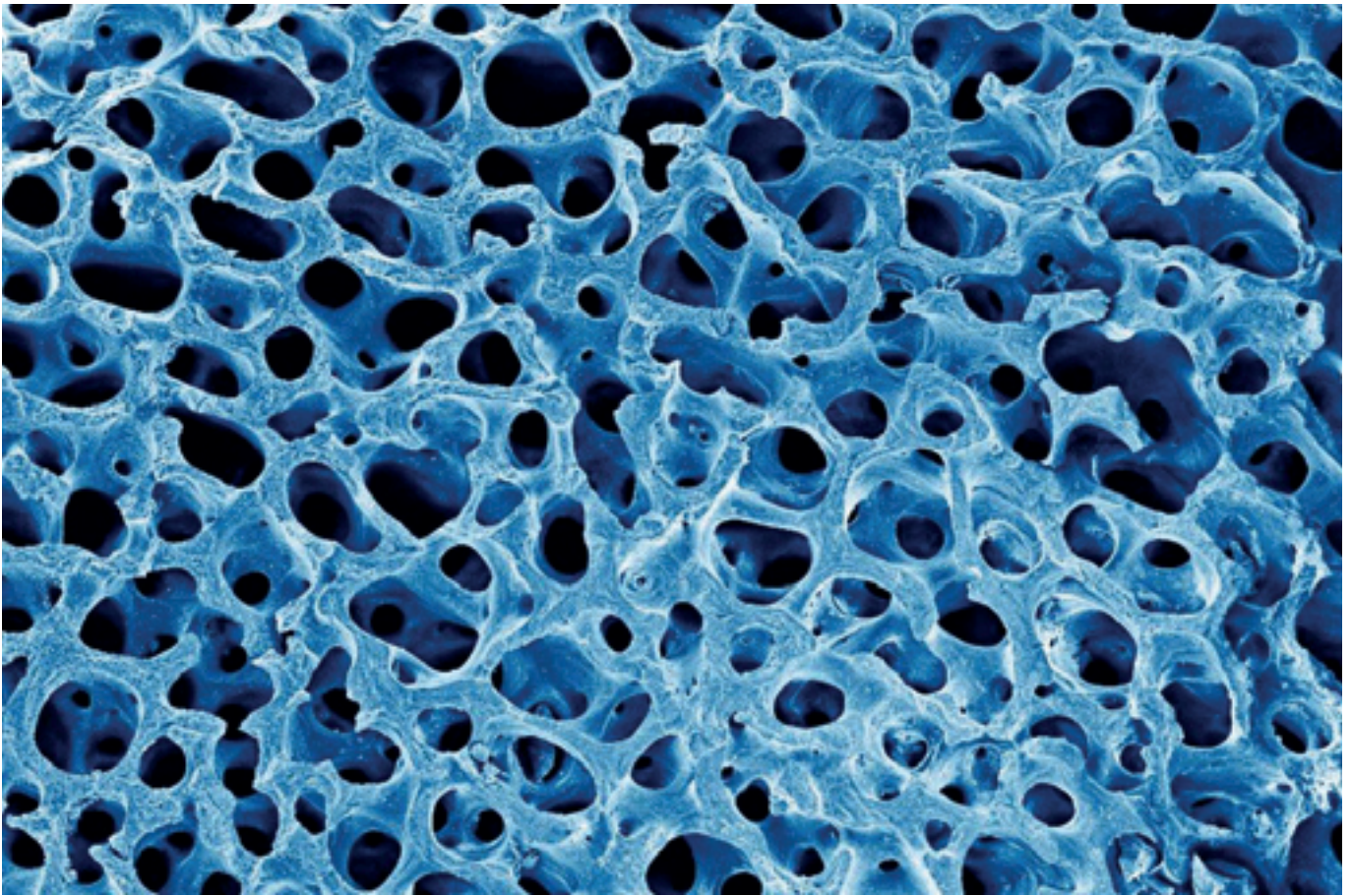


Fig. 5 Scanning electron microscopy image of pore morphology of cancellous bovine bone (50× magnification) by Dr. Michael Bufler. (Courtesy of Geistlich Pharma, 2014)

Regarding xenogeneic graft resorption, Araújo et al. in a dog study showed that the Geistlich Bio-Oss block graft is capable of retaining its dimension with moderate amounts of new bone formed at the base of the graft, while autogenous block grafts undergo 30% and 50% graft resorption.⁷¹ Likewise, De Santis et al. demonstrated superior volumetric stability of deproteinized bovine bone mineral compared with autogenous block grafts harvested from the mandibular ramus in a dog study (0.2 mm vs. 0.9 mm of horizontal resorption, respectively).⁷³

Histological and histomorphometric outcomes

Animal studies have shown that both bovine Geistlich Bio-Oss and equine eHac (Geistlich Pharma) blocks demonstrated similar histological results. In the early stages of healing, the grafts were surrounded by fibrovascular connective tissue with no signs of necrosis, osteolysis or tissue degeneration.⁶⁶ In contrast, Schwarz et al. showed that, after 12 weeks of healing, bovine bone had no signs of degradation, while equine bone presented with an increase in osteoclasts and multinucleate giant

cells.⁶⁷ Additionally, it was shown that the amount and extent of bone ingrowth was higher for equine bone blocks, although this was not of statistical significance. Moreover, Araújo et al. evidenced the lesser osteogenic capacity of xenogeneic blocks, compared with autogenous grafts, by means of mineralized tissue ($47.5 \pm 5.0\%$ vs. $23.3 \pm 3.0\%$, respectively).¹⁷ Similarly, findings by De Santis et al. illustrated the poor incorporation of the block graft into the pristine bone for horizontal ridge augmentation, demonstrating that, while 77% of the autogenous bone presented with vital mineralization, only 5.9% of the deproteinized bovine bone could be identified as new bone formation.⁷³ Therefore, it depends upon the clinician's judgment regarding whether it is preferable to maintain the space or improve predictability by ensuring faster bone turnover.

Future directions

In order to facilitate bone graft adaptation, speed up the surgical procedure and limit any potential graft mobility or dead space, prefabrication of graft scaffolds using advanced computed

tomography is the next wave of bone regeneration and repair.^{74, 75} The idea of these scaffolds for bone regeneration is based upon their ability not only to maintain space, but also to create a 3-D graft structure that mimics the body's own extracellular matrix into which cells attach, migrate and proliferate.^{76, 77} The porosity in such a scaffold biomaterial is important because it allows the transport of nutrients and facilitates tissue ingrowth. Hollister et al. proposed that the ideal scaffold should possess the following four properties: form, function, fixation and formation.⁷⁴ Wagoner Johnson and Herschler further pointed out that scaffolds should possess biocompatibility, conductivity, bioactivity, osteoinductive and interconnected porosity.⁷⁸ Hence, synthetic scaffolds are currently being studied in animal models and *in vitro*.^{79–84} The application of gene therapy (mesenchymal stem cells or human-derived growth factors) via prefabricated scaffolds is the focus of much research at present because growth factors can be used to accelerate the wound-healing process and to promote mesenchymal stem cell migration and maturation.

Conclusion

Allogeneic and xenogeneic bone block grafts represent promising alternatives to autogenous bone for ridge augmentation. Nonetheless, the

evidence supporting the use of xenogeneic block grafts remains minimal; hence, more long-term human studies are needed to validate their effectiveness. In addition, using prefabricated scaffolds impregnated with growth factors provides an interesting field to be further explored.

Competing interests

The authors do not have any financial interests, either directly or indirectly, in the products or information listed in the paper.

Acknowledgments

This paper was partially supported by the University of Michigan's Periodontal Graduate Student Research Fund. In addition, we would like to thank Mr. Hai Bo Wen (Director of Research, Zimmer Biomet Dental), Ms. Vanesa Álvaro (Scientific Marketing Manager, Inibsal Dental) and Dr. Varvara Mitropoulos (Project Manager Clinical Science, Geistlich Pharma) for providing the scanning electron microscopy images. Lastly, we would like to thank Dr. Francisco O'Valle (Department of Pathology, School of Medicine and Institute of Biopathology and Regenerative Medicine, University of Granada, Granada, Spain) for the histological analysis shown in **Figure 4**.

References

1. Carlsson GE, Bergman B, Hedegard B. Changes in contour of the maxillary alveolar process under immediate dentures. A longitudinal clinical and X-ray cephalometric study covering 5 years. → Acta Odontol Scand. 1967 Jun;25(1):45–75.
2. Atwood DA, Coy WA. Clinical, cephalometric, and densitometric study of reduction of residual ridges. → J Prosthet Dent. 1971 Sep;26(3):280–95.
3. Pietrokovski J, Massler M. Alveolar ridge resorption following tooth extraction. → J Prosthet Dent. 1967 Jan;17(1):21–7.
4. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. → Int J Periodontics Restorative Dent. 2003 Aug;23(4):313–23.
5. Hammerle CH, Jung RE, Feloutzis A. A systematic review of the survival of implants in bone sites augmented with barrier membranes (guided bone regeneration) in partially edentulous patients. → J Clin Periodontol. 2002;29 Suppl 3:226–31; discussion 232–3.
6. Tessier P, Kawamoto H, Matthews D, Posnick J, Raulo Y, Tulasne JF, Wolfe SA. Autogenous bone grafts and bone substitutes—tools and techniques: I. A 20,000-case experience in maxillofacial and craniofacial surgery. → Plast Reconstr Surg. 2005 Oct;116(5 Suppl):6S–24S; discussion 92S–94S.
7. Monje A, Monje F, Galindo-Moreno P, Montanero-Fernandez J, Suarez F, Wang HL. Microstructural and densitometric analysis of extra oral bone block grafts for maxillary horizontal bone augmentation: a comparison between calvarial bone and iliac crest. → Clin Oral Implants Res. 2014 Jun;25(6):659–64. Epub 2013 Apr 28.
8. Albrektsson T, Johansson C. Osteoinduction, osteoconduction and osseointegration. → Eur Spine J. 2001 Oct;10 Suppl 2:S96–101.
9. Burchardt H. The biology of bone graft repair. → Clin Orthop Relat Res. 1983 Apr;(174):28–42.
10. Zins JE, Whitaker LA. Membranous versus endochondral bone: implications for craniofacial reconstruction. → Plast Reconstr Surg. 1983 Dec;72(6):778–85.
11. Wennerberg A, Albrektsson T. On implant surfaces: a review of current knowledge and opinions. → Int J Oral Maxillofac Implants. 2010 Jan-Feb;25(1):63–74.

References

12. Brånemark PI. Rehabilitation and osseointegration in clinical reality. → *Int J Oral Maxillofac Implants*. 2003 Sep-Oct;18(5):770–1.
13. Bauer TW, Smith ST. Bioactive materials in orthopaedic surgery: overview and regulatory considerations. → *Clin Orthop Relat Res*. 2002 Feb;(395):11–22.
14. Bauer TW, Muschler GF. Bone graft materials. An overview of the basic science. → *Clin Orthop Relat Res*. 2000 Feb;(371):10–27.
15. Glowacki J, Kaban LB, Murray JE, Folkman J, Mulliken JB. Application of the biological principle of induced osteogenesis for craniofacial defects. → *Lancet*. 1981 May 2;1(8227):959–62.
16. Köndell PA, Mattsson T, Strand P. Immunological responses to maxillary on-lay allogeneic bone grafts. → *Clin Oral Implants Res*. 1996 Dec;7(4):373–7.
17. Araújo PP, Oliveira KP, Montenegro SC, Carreiro AF, Silva JS, Germano AR. Block allograft for reconstruction of alveolar bone ridge in implantology: a systematic review. → *Implant Dent*. 2013 Jun;22(3):304–8.
18. Waasdorp J, Reynolds MA. Allogeneic bone onlay grafts for alveolar ridge augmentation: a systematic review. → *Int J Oral Maxillofac Implants*. 2010 May-Jun;25(3):525–31.
19. Pamula E, Filová E, Bacáková L, Lisa V, Adamczyk D. Resorbable polymeric scaffolds for bone tissue engineering: the influence of their microstructure on the growth of human osteoblast-like MG 63 cells. → *J Biomed Mater Res A*. 2009 May;89(2):432–43.
20. Mellonig JT. Bone grafts in periodontal therapy. → *N Y State Dent J*. 1986;52:27–29.
21. Kurella A, Dahotre NB. Review paper: surface modification for bioimplants: the role of laser surface engineering. → *J Biomater Appl*. 2005 Jul;20(1):5–50.
22. Wang HL, Boyapati L. "PASS" principles for predictable bone regeneration. → *Implant Dent*. 2006 Mar;15(1):8–17.
23. King TW, Brey EM, Youssef AA, Johnston C, Patrick CW Jr. Quantification of vascular density using a semiautomated technique for immunostained specimens. → *Anal Quant Cytol Histol*. 2002 Feb;24(1):39–48.
24. Madeddu P. Therapeutic angiogenesis and vasculogenesis for tissue regeneration. → *Exp Physiol*. 2005 May;90(3):315–26. Epub 2005 Mar 18.
25. Zelzer E, McLean W, Ng YS, Fukai N, Reginato AM, Lovejoy S, D'Amore PA, Olsen BR. Skeletal defects in VEGF(120/120) mice reveal multiple roles for VEGF in skeletogenesis. → *Development*. 2002 Apr;129(8):1893–904.
26. Risau W, Flamme I. Vasculogenesis. → *Annu Rev Cell Dev Biol*. 1995;11:73–91.
27. Flamme I, Frolich T, Risau W. Molecular mechanisms of vasculogenesis and embryonic angiogenesis. → *J Cell Physiol*. 1997 Nov;173(2):206–10.
28. Wallace S, Gellin R. Clinical evaluation of a cancellous block allograft for ridge augmentation and implant placement: a case report. → *Implant Dent*. 2008 Jun;17(2):151–8.
29. De Boer HH. The history of bone grafts. → *Clin Orthop Relat Res*. 1988 Jan;(226):292–8.
30. Leslie HW, Bottenfield S. Donation, banking, and transplantation of allograft tissues. → *Nurs Clin North Am*. 1989 Dec;24(4):891–905.
31. Kao ST, Scott DD. A review of bone substitutes. → *Oral Maxillofac Surg Clin North Am*. 2007 Nov;19(4):513–21, vi.
32. Khan SN, Cammisa FP Jr, Sandhu HS, Diwan AD, Girardi FP, Lane JM. The biology of bone grafting. → *J Am Acad Orthop Surg*. 2005 Jan-Feb;13(1):77–86.
33. Khan SN, Sandhu HS, Parvataneni HK, Girardi FP, Cammisa FP Jr. Bone graft substitutes in spine surgery. → *Bull Hosp Jt Dis*. 2000;59(1):5–10.
34. Strong DM, Friedlaender GE, Tomford WW, Springfield DS, Shives TC, Burchardt H, Enneking WF, Mankin HJ. Immunologic responses in human recipients of osseous and osteochondral allografts. → *Clin Orthop Relat Res*. 1996 May;326:107–14.
35. Mellonig JT. Autogenous and allogeneic bone grafts in periodontal therapy. → *Crit Rev Oral Biol Med*. 1992;3(4):333–52.
36. Sanders JJ, Sepe WW, Bowers GM, Koch RW, Williams JE, Lekas JS, Mellonig JT, Pelleu GB Jr, Gambill V. Clinical evaluation of freeze-dried bone allografts in periodontal osseous defects. Part III. Composite freeze-dried bone allografts with and without autogenous bone grafts. → *J Periodontol*. 1983 Jan;54(1):1–8.
37. Giannoudis PV, Dinopoulos H, Tsidiris E. Bone substitutes: an update. → *Injury*. 2005 Nov;36 Suppl 3:S20–7.
38. Krieger RJ, Schaller C, Clusmann H. Cranioplasty for large skull defects with PMMA (polymethylmethacrylate) or Tutoplast processed autogenic bone grafts. → *Zentralbl Neurochir*. 2007 Nov;68(4):182–9. Epub 2007 Oct 26.
39. Pachence JM. Collagen-based devices for soft tissue repair. → *J Biomed Mater Res*. 1996 Spring;33(1):35–40.
40. Acocella A, Bertolai R, Ellis E 3rd, Nissan J, Sacco R. Maxillary alveolar ridge reconstruction with monocortical fresh-frozen bone blocks: a clinical, histological and histomorphometric study. → *J Craniomaxillofac Surg*. 2012 Sep;40(6):525–33. Epub 2011 Nov 9.
41. Barone A, Varanini P, Orlando B, Tonelli P, Covani U. Deep-frozen allogeneic onlay bone grafts for reconstruction of atrophic maxillary alveolar ridges: a preliminary study. → *J Oral Maxillofac Surg*. 2009 Jun;67(6):1300–6.
42. Chaushu G, Mardinger O, Peleg M, Ghelfan O, Nissan J. Analysis of complications following augmentation with cancellous block allografts. → *J Periodontol*. 2010 Dec;81(12):1759–64. Epub 2010 Aug 3.
43. Contar CM, Sarot JR, da Costa MB, Bordini J, de Lima AA, Alanis LR, Trevilatto PC, Machado MA. Fresh-frozen bone allografts in maxillary ridge augmentation: histologic analysis. → *J Oral Implantol*. 2011 Apr;37(2):223–31. Epub 2010 Jun 14.
44. Contar CM, Sarot JR, Bordini J Jr, Galvao GH, Nicolau GV, Machado MA. Maxillary ridge augmentation with fresh-frozen bone allografts. → *J Oral Maxillofac Surg*. 2009 Jun;67(6):1280–5.
45. Deluiz D, Oliveira LS, Pires FR, Tinoco EM. Time-dependent changes in fresh-frozen bone block grafts: tomographic, histologic, and histomorphometric findings. → *Clin Implant Dent Relat Res*. 2015 Apr;17(2):296–306. Epub 2013 Jul 9.
46. Lumetti S, Consolo U, Galli C, Multinu A, Piersanti L, Bellini P, Manfredi E, Corinaldesi G, Zaffe D, Macaluso GM, Marchetti C. Fresh-frozen bone blocks for horizontal ridge augmentation in the upper maxilla: 6-month outcomes of a randomized controlled trial. → *Clin Implant Dent Relat Res*. 2014 Feb;16(1):116–23. Epub 2012 Apr 24.
47. Lyford RH, Mills MP, Knapp CI, Scheyer ET, Mellonig JT. Clinical evaluation of freeze-dried block allografts for alveolar ridge augmentation: a case series. → *Int J Periodontics Restorative Dent*. 2003 Oct;23(5):417–25.
48. Macedo LG, Mazzucchelli-Cosmo LA, Macedo NL, Monteiro AS, Sendyk WR. Fresh-frozen human bone allograft in vertical ridge augmentation: clinical and tomographic evaluation of bone formation and resorption. → *Cell Tissue Bank*. 2012 Dec;13(4):577–86. Epub 2011 Aug 3.
49. Nissan J, Mardinger O, Calderon S, Romanos GE, Chaushu G. Cancellous bone block allografts for the augmentation of the anterior atrophic maxilla. → *Clin Implant Dent Relat Res*. 2011 Jun;13(2):104–11.
50. Nissan J, Romanos GE, Mardinger O, Chaushu G. Immediate nonfunctional loading of single-tooth implants in the anterior maxilla following augmentation with freeze-dried cancellous block allograft: a case series. → *Int J Oral Maxillofac Implants*. 2008 Jul-Aug;23(4):709–16.
51. Nissan J, Gross O, Mardinger O, Ghelfan O, Sacco R, Chaushu G. Post-traumatic implant-supported restoration of the anterior maxillary teeth using cancellous bone block allografts. → *J Oral Maxillofac Surg*. 2011 Dec;69(12):e513–8. Epub 2011 Oct 8.
52. Novell J, Novell-Costa F, Ivorra C, Farinas O, Munilla A, Martinez C. Five-year results of implants inserted into freeze-dried block allografts. → *Implant Dent*. 2012 Apr;21(2):129–35.

References

53. Peleg M, Sawatari Y, Marx RN, Santoro J, Cohen J, Bejarano P, Malinin T. Use of corticocancellous allogeneic bone blocks for augmentation of alveolar bone defects. → *Int J Oral Maxillofac Implants*. 2010 Jan-Feb;25(1):153–62.
54. Spin-Neto R, Stavropoulos A, Dias Pereira LA, Marcantonio E Jr, Wenzel A. Fate of autologous and fresh-frozen allogeneic block bone grafts used for ridge augmentation. A CBCT-based analysis. → *Clin Oral Implants Res*. 2013 Feb;24(2):167–73. Epub 2011 Oct 21.
55. Spin-Neto R, Landazuri Del Barrio RA, Pereira LA, Marcantonio RA, Marcantonio E, Marcantonio E Jr. Clinical similarities and histological diversity comparing fresh frozen onlay bone blocks allografts and autografts in human maxillary reconstruction. → *Clin Implant Dent Relat Res*. 2013 Aug;15(4):490–7. Epub 2011 Aug 11.
56. Wallace S, Gellin R. Clinical evaluation of freeze-dried cancellous block allografts for ridge augmentation and implant placement in the maxilla. → *Implant Dent*. 2010 Aug;19(4):272–9.
57. Monje A, Pikos MA, Chan HL, Suarez F, Gargallo-Albiol J, Hernández-Alfaro F, Galindo-Moreno P, Wang HL. On the feasibility of utilizing allogeneic bone blocks for atrophic maxillary augmentation. → *Biomed Res Int*. 2014;2014:814578. Epub 2014 Sep 11.
58. Chaushu G, Manor Y, Shoshani Y, Taicher S. Risk factors contributing to symptomatic plate removal in maxillofacial trauma patients. → *Plast Reconstr Surg*. 2000 Feb;105(2):521–5.
59. Flamme I, Fröhlich T, von Reutern M, Kappel A, Damert A, Risau W. HRF, a putative basic helix-loop-helix-PAS-domain transcription factor is closely related to hypoxia-inducible factor-1 alpha and developmentally expressed in blood vessels. → *Mech Dev*. 1997 Apr;63(1):51–60.
60. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? → *Int J Oral Maxillofac Implants*. 2007;22 Suppl:49–70.
61. Araújo MG, Carmagnola D, Berglundh T, Thilander B, Lindhe J. Orthodontic movement in bone defects augmented with Bio-Oss. An experimental study in dogs. → *J Clin Periodontol*. 2001 Jan;28(1):73–80.
62. Araújo MG, Lindhe J. Ridge preservation with the use of Bio-Oss collagen: A 6-month study in the dog. → *Clin Oral Implants Res*. 2009 May;20(5):433–40.
63. Felice P, Marchetti C, Iezzi G, Piattelli A, Worthington H, Pellegrino G, Esposito M. Vertical ridge augmentation of the atrophic posterior mandible with interpositional bloc grafts: bone from the iliac crest vs. bovine anorganic bone. Clinical and histological results up to one year after loading from a randomized-controlled clinical trial. → *Clin Oral Implants Res*. 2009 Dec;20(12):1386–93. Epub 2009 Aug 4.
64. Simion M, Fontana F, Rasperini G, Maiorana C. Vertical ridge augmentation by expanded-polytetrafluoroethylene membrane and a combination of intraoral autogenous bone graft and deproteinized anorganic bovine bone (Bio Oss). → *Clin Oral Implants Res*. 2007 Oct;18(5):620–9.
65. Felice P, Piana L, Checchi L, Corvino V, Nannmark U, Piattelli M. Vertical ridge augmentation of an atrophic posterior mandible with an inlay technique and cancellous equine bone block: a case report. → *Int J Periodontics Restorative Dent*. 2013 Mar-Apr;33(2):159–66.
66. Fontana F, Rocchietta I, Dellavia C, Nevins M, Simion M. Biocompatibility and manageability of a new fixable bone graft for the treatment of localized bone defects: preliminary study in a dog model. → *Int J Periodontics Restorative Dent*. 2008 Dec;28(6):601–7.
67. Schwarz F, Ferrari D, Balic E, Buser D, Becker J, Sager M. Lateral ridge augmentation using equine- and bovine-derived cancellous bone blocks: a feasibility study in dogs. → *Clin Oral Implants Res*. 2010 Sep;21(9):904–12. Epub 2010 May 9.
68. Botticelli D, Berglundh T, Lindhe J. The influence of a biomaterial on the closure of a marginal hard tissue defect adjacent to implants. An experimental study in the dog. → *Clin Oral Implants Res*. 2004 Jun;15(3):285–92.
69. Carmagnola D, Adriaens P, Berglundh T. Healing of human extraction sockets filled with Bio-Oss. → *Clin Oral Implants Res*. 2003 Apr;14(2):137–43.
70. Andia I, Maffulli N. Platelet-rich plasma for muscle injury and tendinopathy. → *Sports Med Arthrosc*. 2013 Dec;21(4):191–8.
71. Araújo MG, Sonohara M, Hayacibara R, Cardaropoli G, Lindhe J. Lateral ridge augmentation by the use of grafts comprised of autologous bone or a biomaterial. An experiment in the dog. → *J Clin Periodontol*. 2002 Dec;29(12):1122–31.
72. Steigmann M. A bovine-bone mineral block for the treatment of severe ridge deficiencies in the anterior region: a clinical case report. → *Int J Oral Maxillofac Implants*. 2008 Jan-Feb;23(1):123–8.
73. De Santis E, Lang NP, Favero G, Beolchini M, Morelli F, Botticelli D. Healing at mandibular block-grafted sites. An experimental study in dogs. → *Clin Oral Implants Res*. 2015 May;26(5):516–22. Epub 2014 Jun 12.
74. Hollister SJ, Murphy WL. Scaffold translation: barriers between concept and clinic. → *Tissue Eng Part B Rev*. 2011 Dec;17(6):459–74. Epub 2011 Sep 21.
75. Pilipchuk SP, Plonka AB, Monje A, Taut AD, Lanis A, Kang B, Giannobile WV. Tissue engineering for bone regeneration and osseointegration in the oral cavity. → *Dent Mater*. 2015 Apr;31(4):317–38. Epub 2015 Feb 18.
76. Billstrom GH, Blom AW, Larsson S, Beswick AD. Application of scaffolds for bone regeneration strategies: current trends and future directions. → *Injury*. 2013 Jan;44 Suppl 1:S28–33.
77. Yannas IV. Synthesis of tissues and organs. → *ChemBiochem*. 2004 Jan 3;5(1):26–39.
78. Wagoner Johnson AJ, Herschler BA. A review of the mechanical behavior of CaP and CaP/polymer composites for applications in bone replacement and repair. → *Acta Biomater*. 2011 Jan;7(1):16–30. Epub 2010 Jul 21.
79. Rosa V. What and where are the stem cells for dentistry? → *Singapore Dent J*. 2013 Dec;34(1):13–8.
80. Iwata T, Yamato M, Ishikawa I, Ando T, Okano T. Tissue engineering in periodontal tissue. → *Anat Rec (Hoboken)*. 2014 Jan;297(1):16–25. Epub 2013 Dec 2.
81. Jiang ZQ, Liu HY, Zhang LP, Wu ZQ, Shang DZ. Repair of calvarial defects in rabbits with platelet-rich plasma as the scaffold for carrying bone marrow stromal cells. → *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2012 Mar;113(3):327–33.
82. Khojasteh A, Behnia H, Hosseini FS, Dehghan MM, Abbasnia P, Abbas FM. The effect of PCL-TCP scaffold loaded with mesenchymal stem cells on vertical bone augmentation in dog mandible: a preliminary report. → *J Biomed Mater Res B Appl Biomater*. 2013 Jul;101(5):848–54. Epub 2013 Jan 29.
83. Kim S, Jung UW, Lee YK, Choi SH. Effects of biphasic calcium phosphate bone substitute on circumferential bone defects around dental implants in dogs. → *Int J Oral Maxillofac Implants*. 2011 Mar-Apr;26(2):265–73.
84. Nevins ML, Reynolds MA. Tissue engineering with recombinant human platelet-derived growth factor BB for implant site development. → *Compend Contin Educ Dent*. 2011 Mar;32(2):18, 20–7; quiz 28, 40.
85. Jingxu L, Feng X, Byung-Ho C, Seung-Mi J. Minimally Invasive Ridge Augmentation Using Xenogenous Bone Blocks in an Atrophied Posterior Mandible: A Clinical and Histological Study. → *Implant Dent*. 2013;22:112–116.

The Dental Tribune International Magazines

www.dental-tribune.com

I would like to subscribe to

- | | |
|--|--|
| <input type="checkbox"/> CAD/CAM | <input type="checkbox"/> ortho** |
| <input type="checkbox"/> Clinical Masters* | <input type="checkbox"/> prevention* |
| <input type="checkbox"/> cosmetic dentistry* | <input type="checkbox"/> roots |
| <input type="checkbox"/> implants | <input type="checkbox"/> Journal of Oral Science |
| <input type="checkbox"/> laser | & Rehabilitation*** |

EUR 44 per year (4 issues per year; incl. shipping and VAT for customers in Germany) and EUR 46 per year (4 issues per year; incl. shipping for customers outside Germany).

* EUR 12 per year (1 issue per year; incl. shipping and VAT for customers in Germany) and EUR 14 per year (1 issue per year; incl. shipping for customers outside Germany).

** EUR 22 per year (2 issues per year; incl. shipping and VAT for customers in Germany) and EUR 23 per year (2 issues per year; incl. shipping for customers outside Germany).

*** EUR 200 per year (4 issues per year; incl. shipping and VAT).

Your subscription will be renewed automatically every year until a written cancellation is sent to Dental Tribune International GmbH, Holbeinstr. 29, 04229 Leipzig, Germany, six weeks prior to the renewal date.

Shipping Address

Name	
Address	
Zip Code, City	Country
E-mail	
Date, Signature	

☐ PayPal ☐ Credit Card

Credit Card Number

Expiration Date

Security Code

SUBSCRIBE NOW!

F +49 341 48474 173
subscriptions@dental-tribune.com

dti Dental
Tribune
International

Retrospective analysis of periimplantitis therapy of 158 implants

Abstract

Objective

The objective of the retrospective analysis was to evaluate the efficacy of periimplantitis treatment up to a five-year observation period.

Materials and methods

Patients treated for periimplantitis between 2009 and 2015 were included. Before therapy, the patients underwent professional tooth cleaning, defect class diagnosis and thorough mechanical cleaning of the implant surface. In the case of intraosseous defects, a deproteinized bovine bone mineral and a native bilayer collagen membrane were used according to the concept of guided bone regeneration. Retrospectively, plaque index, full-mouth bleeding on probing and probing pocket depth were analyzed before the therapy and at recall visits up to 56 months after therapy.

Results

Out of 22,724 implants, 107 patients with 158 implants underwent periimplantitis therapy and these had been in place for nine months to 15 years. Fifteen implants (9.49%) had to be extracted despite therapy. Most of the periimplantitis infections had occurred within five years after implantation (108 implants; 68.4%). In 45 implants (28.5%), therapy had included guided bone regeneration. Before therapy, bleeding on probing was 100%. Bleeding on probing was absent in 50.0% of implants at 12 months and in 73.1% of implants examined 49–56 months post-therapy. Probing pocket depth was reduced from 4.92 ± 1.93 mm before therapy to 2.67 ± 0.88 mm after 12 months and remained stable up to 56 months post-therapy (2.71 ± 0.30 mm).

Conclusion

Using a treatment approach including a presurgical hygiene phase and considering the defect morphology, periimplantitis therapy was mostly successful in terms of implant survival (90.5%).

Keywords

Periimplantitis, oral hygiene, defect class, guided bone regeneration.

Jörg-Ulf Wiegner,^a Hermann Klinsmann^a
& Toralf Kömmling^b

^a Private practice, Saalfeld, Germany
^b Private practice, Gera, Germany

Corresponding author:

Dr. Jörg-Ulf Wiegner
Saalstraße 35
07318 Saalfeld
Germany

T: +49 3671 460933
wiegner@saalepraxis.de

How to cite this article:

Wiegner JU, Klinsmann H, Kömmling T.
Retrospective analysis of periimplantitis therapy
of 158 implants.
J Oral Science Rehabilitation.
2017 Mar;3(1):32–42.

Introduction

Implant therapy is a well-established method to restore missing teeth. However, periimplant tissue infections due to biofilm formation may compromise implant survival. The term “periimplantitis” describes an inflammatory process in the periimplant mucosa with additional signs of bone loss.¹ Periimplantitis occurs in around 10% of implants and 20% of patients.^{1–3} A very recent meta-analysis reported a mean prevalence of 22% (CI: 14–30%) for periimplantitis.⁴

Risk factors for periimplantitis are poor plaque control, history of periodontitis, smoking, uncontrolled diabetes, periimplant cement residue, genetic factors, occlusal overload and history of periimplantitis.^{5,6} Current strategies for periimplantitis therapy include a pretreatment phase with professional tooth cleaning, optimization of plaque control with prosthesis adjustment if necessary and nonsurgical debridement.^{7–9} Afterward, in the surgical phase, a full-thickness flap is prepared and the contaminated implant surface is thoroughly cleaned. Intraosseous defects can be filled using a bone substitute or tissue graft material with or without a resorbable membrane. The postsurgical protocol includes systemic antibiotic therapy and chlorhexidine rinsing during the healing phase, followed by the maintenance phase with regular recall visits, ranging from three to six months.

Regenerative surgical therapy has been shown to predictably obtain partial to full defect fill,¹⁰ although the outcome may be influenced by the defect morphology¹¹ and implant surface.¹² According to the concept of guided bone regeneration (GBR), the use of a deproteinized bovine bone mineral (DBBM) either with or without a native bilayer collagen membrane (NBCM) has been evaluated in various clinical studies and demonstrated marked short-term clinical improvements and promising long-term results.^{12–16} The aim of our retrospective evaluation was to analyze the efficacy of the periimplantitis treatment with or without bone augmentation in patients over a long-term observation period up to five years post-therapy.

Materials and methods

Study population

The retrospective evaluation included 107 patients with 158 implants that were treated for periimplantitis between 2009 and 2015. Im-

plants had been inserted between 1993 and 2014 by the same surgeon (JUW) according to the manufacturers' instructions. Implant systems included Steri-Oss (Nobel Biocare, Zurich, Switzerland), CAMLOG implant system (Cylinder Line, Screw Cylinder Line, Root-Line, SCREW-LINE, SCREW-LINE Promote plus, iSy, CAMLOG Biotechnologies, Basel, Switzerland), ITI and Straumann implants (Straumann, Basel, Switzerland), FRIALIT 2 (Dentsply Sirona, Mannheim, Germany), XiVE (Dentsply Sirona), ASTRA TECH OsseoSpeed (Dentsply Sirona), IMZ Twin-Plus (Dentsply Sirona) and ANKYLOS (Dentsply Sirona). If necessary, bone augmentation procedures were performed before or during the implantation. After completion of the healing phase, the patients were referred back to their dentists or prosthodontists for further prosthetic treatment and follow-up. Later on, some of those patients were referred to our practice again because of periimplantitis.

Therapy

Before periimplantitis treatment, clinical and radiographic evaluation took place. In the case of acute inflammation, anti-inflammatories were locally applied. Patients underwent professional tooth cleaning and periodontal therapy in the case of generalized periodontitis.

Periimplantitis was classified and treated in accordance with Schwarz et al. (**Fig. 1**).^{17,18} After exposing the defects and removing granulation tissue, implantoplasty was performed using diamonds rotary instruments and Arkansas stones finishing burs. Defects were cleaned with sterile saline. Intraosseous defects (defect Classes Ib, c, d and e; **Fig. 1**) were augmented according to the treatment protocol using a DBBM (Geistlich Bio-Oss spongiosa granules, Geistlich Pharma, Wolhusen, Switzerland) and an NBCM (Geistlich Bio-Gide Perio, Geistlich Pharma). The surgical area was carefully closed, a periodontal wound dressing applied (Coe-Pak, GC Europe, Leuven, Belgium) and a radiographic evaluation performed. Patients were advised to rinse cautiously with chlorhexamed 0.2% (GSK, London, U.K.) from the first day postsurgery for one week. Antibiotics were given at the discretion of the surgeon starting 24 h before surgery until suture removal eight days postsurgery. Patients were followed up according to a strict recall schedule in our practice. If necessary, supplementary therapy, such as gingivectomy or implantoplasty, was performed during the follow-up phase.

Fig. 1

Defect classes and treatment protocol according to Schwarz et al.^{17, 18}

Ia (buccal vertical bone dehiscence),

Ib (buccal dehiscence and semicircular bone defect to the middle of the implant body),

Ic (buccal dehiscence, circular bone defect, maintained lingual solid bone),

Id (buccal and lingual dehiscence defects),

Ie (circular bone resorption, buccal and oral compacta maintained),

II (supra-alveolar circumferential bone loss).

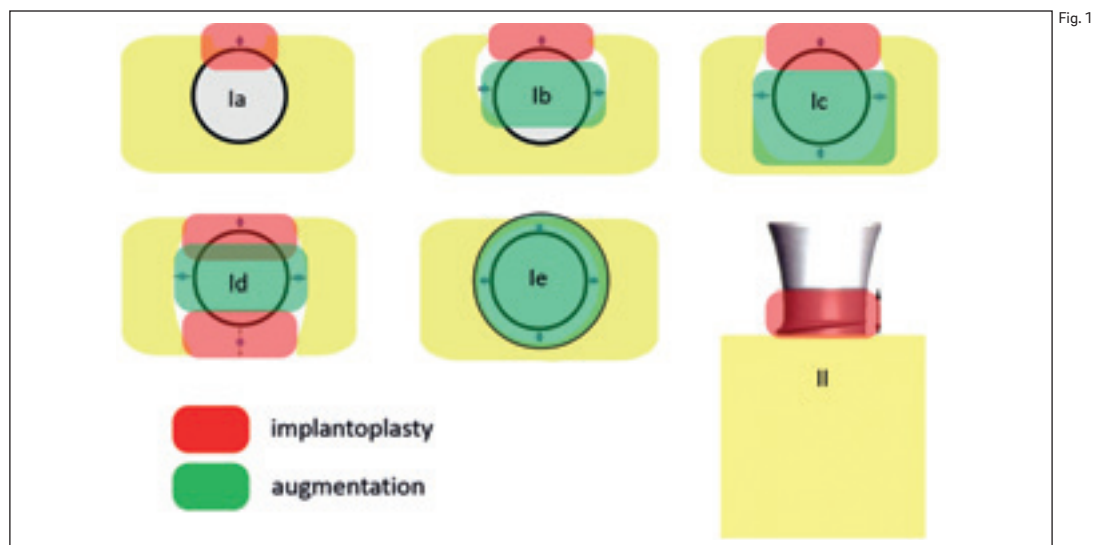


Fig. 1

Analysis

Both hopeless implants extracted before the periimplantitis therapy and implants treated by a different dentist with incomplete data were not included in our evaluation. Data for the clinical evaluation were retrieved retrospectively from the patient files in our practice and included plaque index, full-mouth bleeding on probing (BOP) and probing pocket depth (PPD). PPD was measured from the mucosal margin to the bottom of the probeable pocket mesially, distally, orally and vestibularly at the start of the periimplantitis therapy and during recall visits in our practice at 3, 6, 9, 12, 24, 36, 48 and 49 to 56 months. In order to evaluate possible risk factors for periimplantitis, signs of prosthetic deficiencies at the start of the therapy were analyzed, as was history of periimplantitis. Additionally, patient files were analyzed to identify smoking, bisphosphonate intake and diabetic patients at the time of implantation.

In order to analyze the prevalence of periimplantitis per indication, implants were allocated to one of the following indication classes as defined at the consensus conference of the BDIZ EDI, DGI, DGMKG, DGZI and BDO (national German dental associations) on Oct. 8, 2014:

- Ia: single-tooth replacement in the anterior area;
- Ib: single-tooth replacement in the posterior area;
- IIa: interdental space;
- IIb: free-end situation;
- IIc: greatly reduced residual dentition; and
- III: edentulous jaw.

In an additional subanalysis, implants inserted between 1993 and 2014 were evaluated for primary indication classes and the rate of explanations.

Statistical analysis

The following exploratory tests were performed:

- To test the null hypothesis of no association between indication class and the need for implant therapy, the approximate chi-squared test for association was used. The significance level was set at 5%.
- All pairs of indication classes were tested against each other using the same chi-squared tests. In order to avoid inflation of Type I error due to multiple testing, all *p*-values were multiplied by the number of such comparisons (15; Bonferroni correction).
- Each indication class was compared to all other indication classes pooled using the chi-squared tests already mentioned above. Since there were six comparisons, *p*-values were multiplied by six (Bonferroni correction) to account for multiple testing.

Results

Between 1993 and 2014, a total of 22,724 implants were inserted in 9,429 patients in our practice and patients were then referred back to their prosthodontists or treating dentists for prostheses. During the observation period of our evaluation (2009–2015), 516 of those patients

Fig. 2

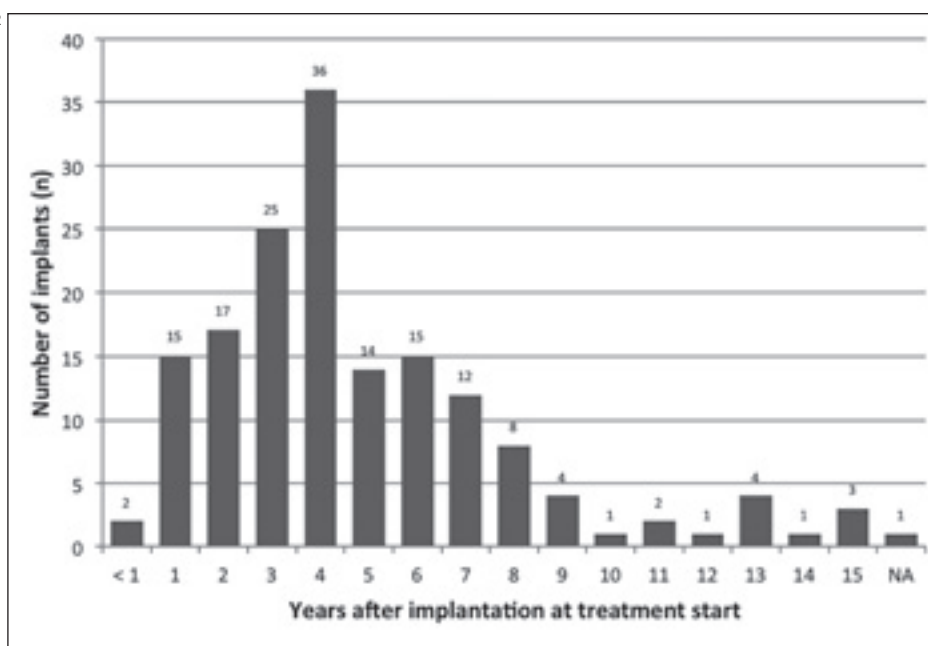


Fig. 2

Time after implantation in years at start of periimplantitis therapy. (NA = unknown; $n = 158$).

with a total of 637 implants were referred back to our practice owing to periimplantitis. Of these, 471 implants were deemed hopeless and extracted immediately (73.9%). Eight implants for which periimplantitis therapy was planned had to be extracted at the start of the treatment phase. Thus, periimplantitis therapy was initiated for 158 implants in 107 patients (24.8%). Analysis of the original patient files established that cemented reconstructions were used in 128 implants (77.6%) and screw-retained reconstructions in 37 implants (22.4%). The 158 implants had been in place for nine months to 15 years (**Fig. 2**). Most of the periimplantitis infections had occurred within the first five years after implant insertion (108 implants; 68.4%). In one implant, this period was retrospectively not clearly determinable. Seventy-two implants treated with periimplantitis therapy were located in the maxilla (45.6%) and 86 in the mandible (54.4%). The distribution of the implantation sites is shown in **Figures 3a and b**. Before the observation period of our evaluation, 17 implants had been explanted owing to periimplantitis and replaced (10.8%). The newly inserted implants developed periimplantitis again.

Of the patients referred back to our practice and treated for periimplantitis, 41 were male (38.3%) and 66 were female (61.7%). The mean age of the 107 patients at the start of the periimplantitis therapy was 58 ± 11 (23–85) years. At the time of implantation, 18 of the 107 patients

were smokers (16.8%), three had received bisphosphonate treatment (3.80%), five had diabetes mellitus (4.67%) and 81 did present any conspicuous medical findings (75.7%), based on the original patient files. The following prosthetic deficiencies of the implants were identified in 25 of the 107 patients (36%): formation of marginal gaps, overcontouring, overload, insufficient biological width, unnecessary splinting and cement residue.

In 52 of the 107 patients (48.6%), generalized periodontitis was diagnosed for 79 implants (50.0%) and treated accordingly. The distribution of the periimplantitis defect classes is shown in **Figure 4**. In 45 implants (28.5%), the therapy included GBR using a DBBM and an NBCM. The remaining 113 implants underwent professional tooth cleaning and were treated according to the implantoplasty protocol. At the start of the periimplantitis therapy, the BOP of the 158 implants was 100.0% and the plaque index was on average $48.5 \pm 26.6\%$ ($n = 88$).

After initiation of the periimplantitis therapy, the mean vestibular PPD of the 158 implants was reduced from 4.93 ± 1.94 mm to 2.67 ± 0.88 mm after 12 months ($n = 123$) and 2.71 ± 0.30 mm after 49–56 months ($n = 32$; **Figs. 5a & b**), therefore on average below the level stated for the definition of periimplantitis.⁹ Stable PPD reduction was also found for implants with long-term follow-up data 49–56 months post-therapy (**Fig. 6**). BOP was absent in 50.0% of 58 analyzed implants at 12 months

Figs. 3a & b

Number of affected implants per site: **(a)** maxilla
(b) mandible. ($n = 158$).

Fig. 4

Defect classes at the start of periimplantitis therapy according to Schwarz et al.^{17, 27}

Figs. 5a & b

(a) Box plot of pocket depth preoperatively and three, six, nine and 12 months after the start of periimplantitis therapy. (m = mesial; v = vestibular; d = distal; o = oral; $n = 123-158$).

(b) Box plot of pocket depth after 24, 36, 48, and 49 and more months after the start of periimplantitis therapy. (m = mesial; v = vestibular; d = distal; o = oral; $n = 16-158$).

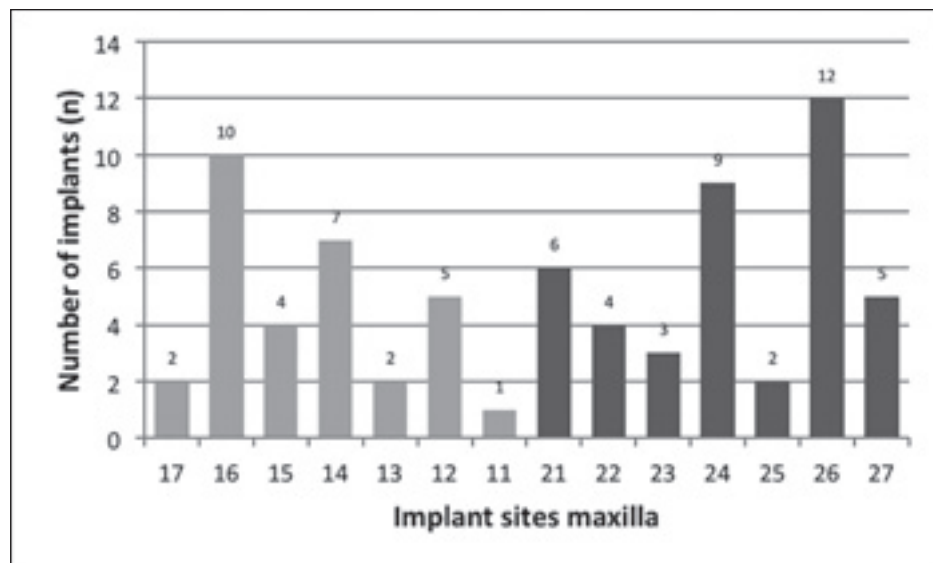


Fig. 3a

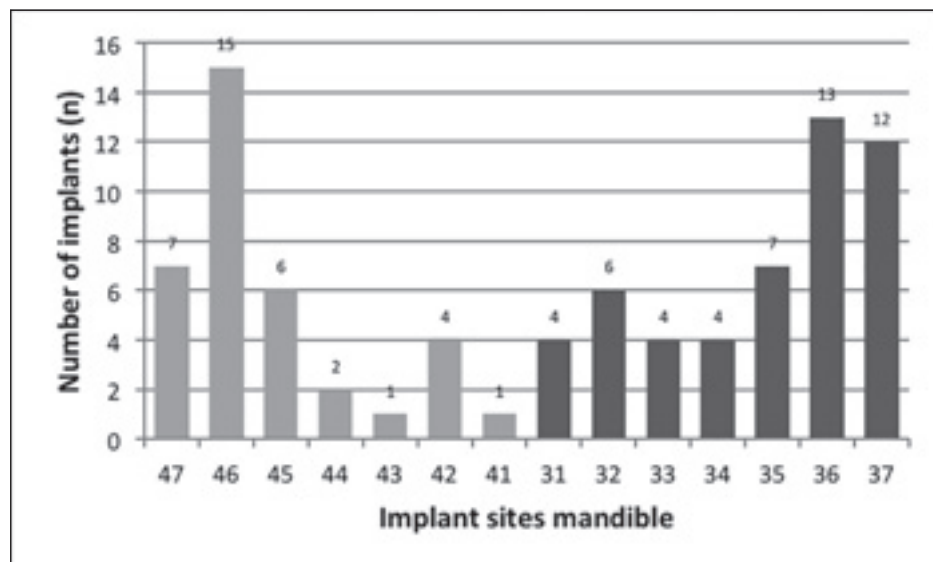


Fig. 3b

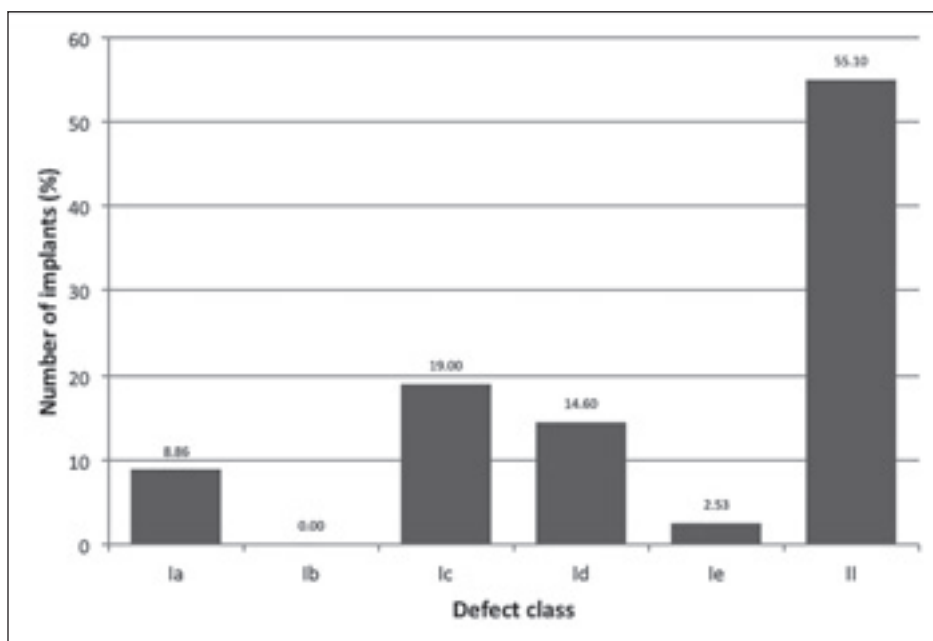


Fig. 4

Fig. 5a

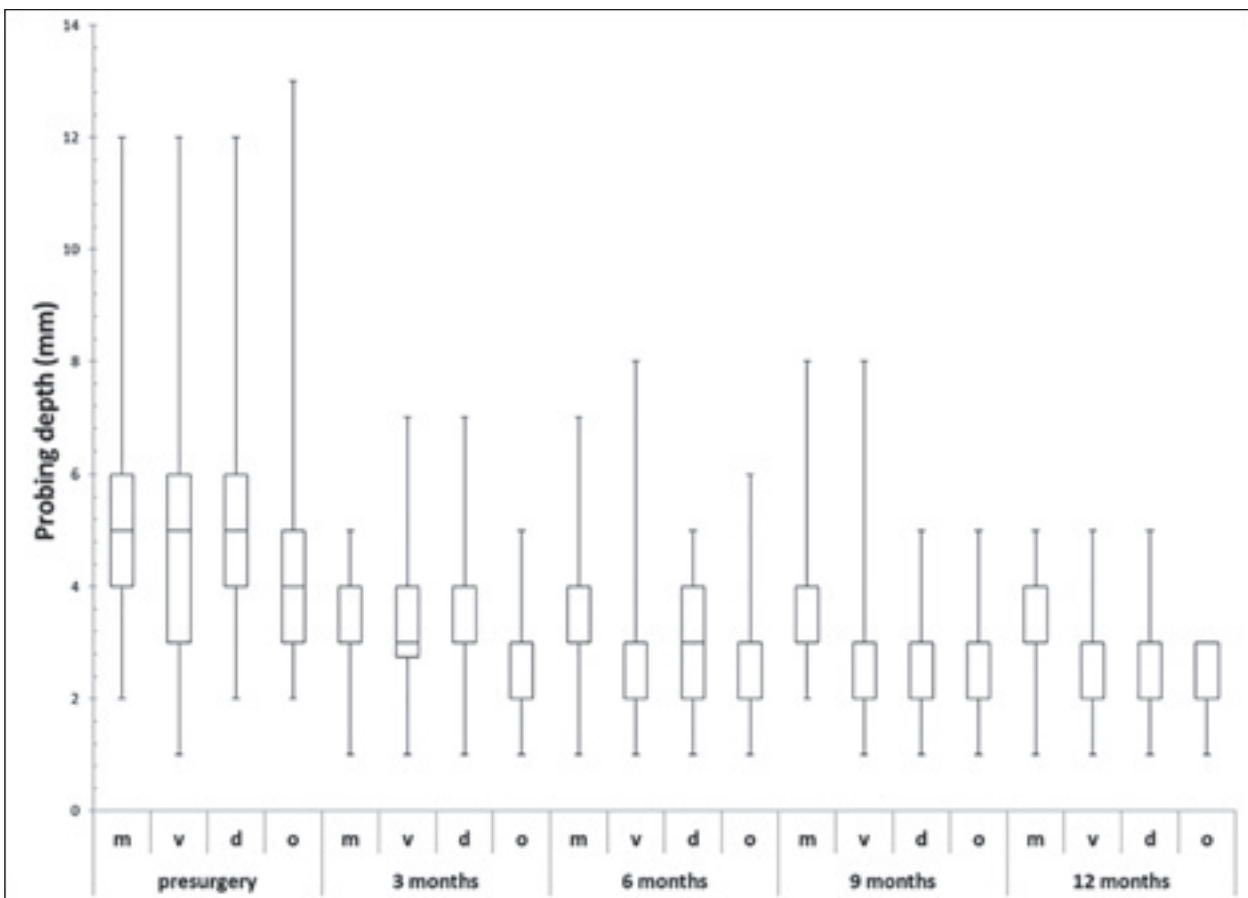


Fig. 5b

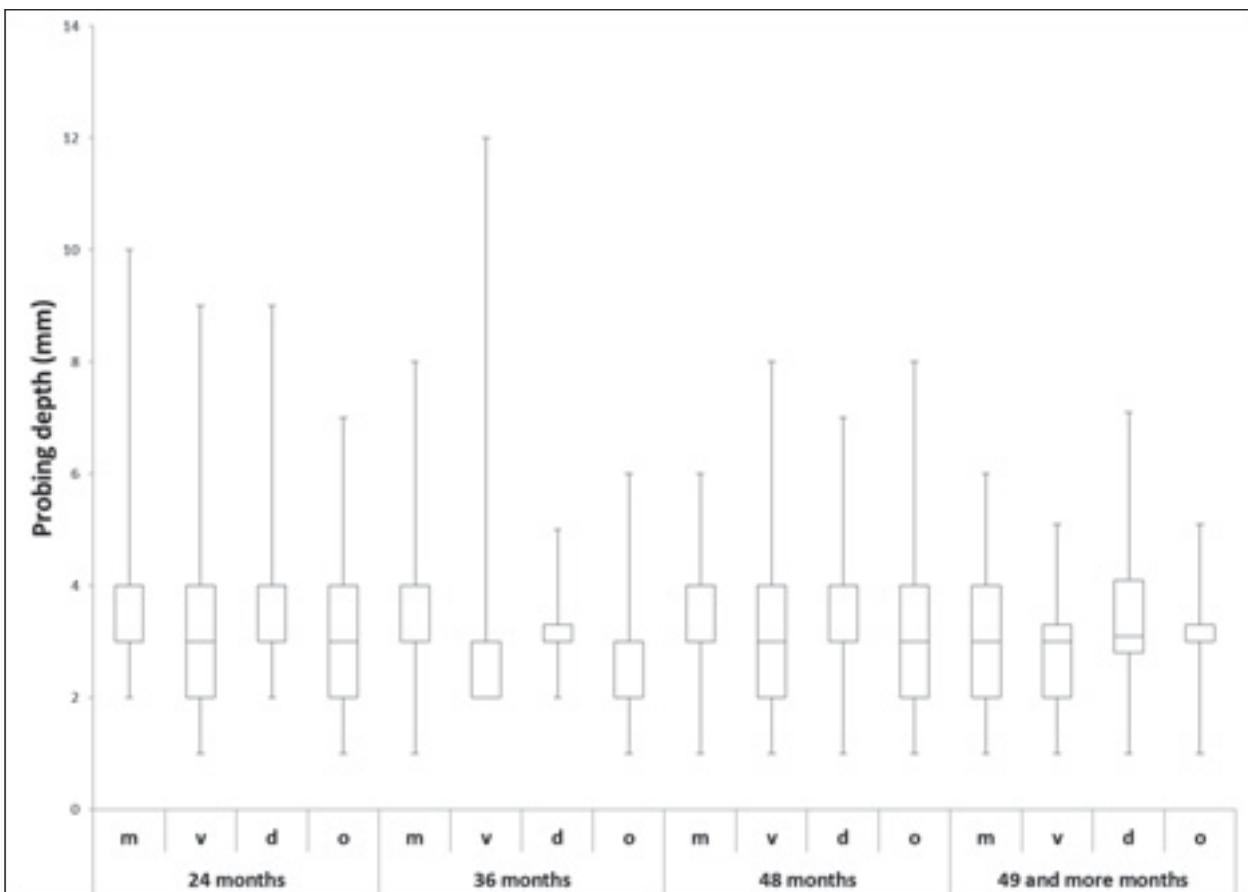


Fig. 6

Pocket depth after 49 and more months compared with pocket depth at 12 months in all treated implants. (m = mesial; v = vestibular; d = distal; o = oral; 12 months: $n = 158$; 49 and more months: $n = 16$).

Fig. 7

Number of implants showing BOP before periimplantitis therapy and at recall visits up to 49 and more months after the start of the therapy. ($n = 8-158$).

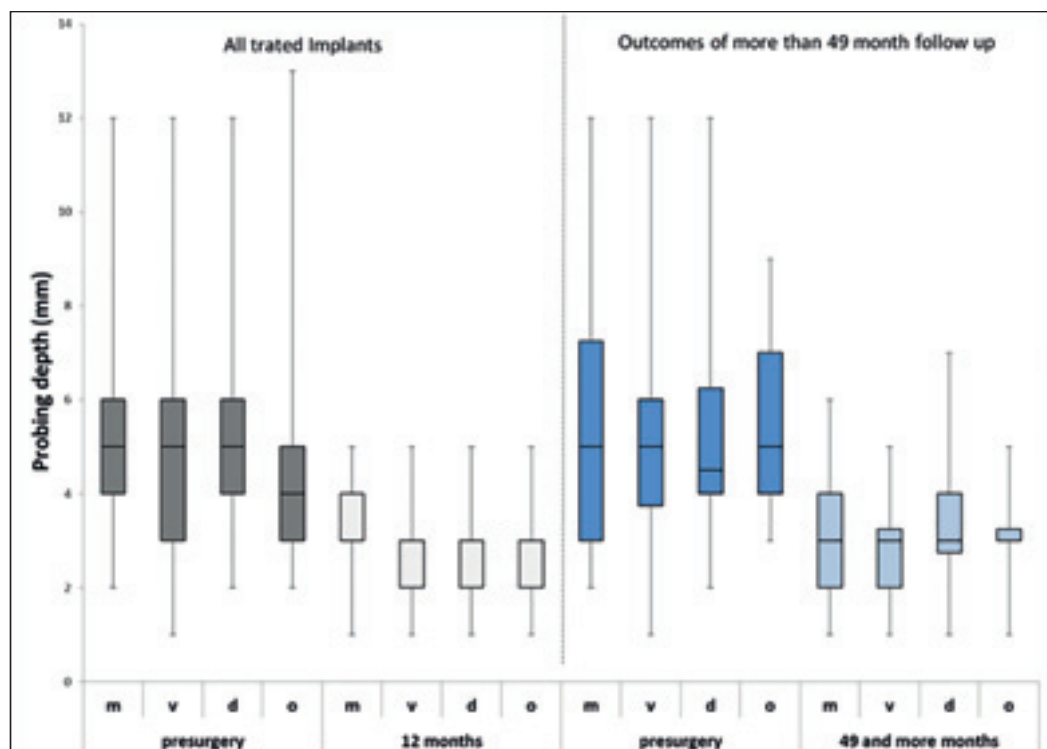


Fig. 6

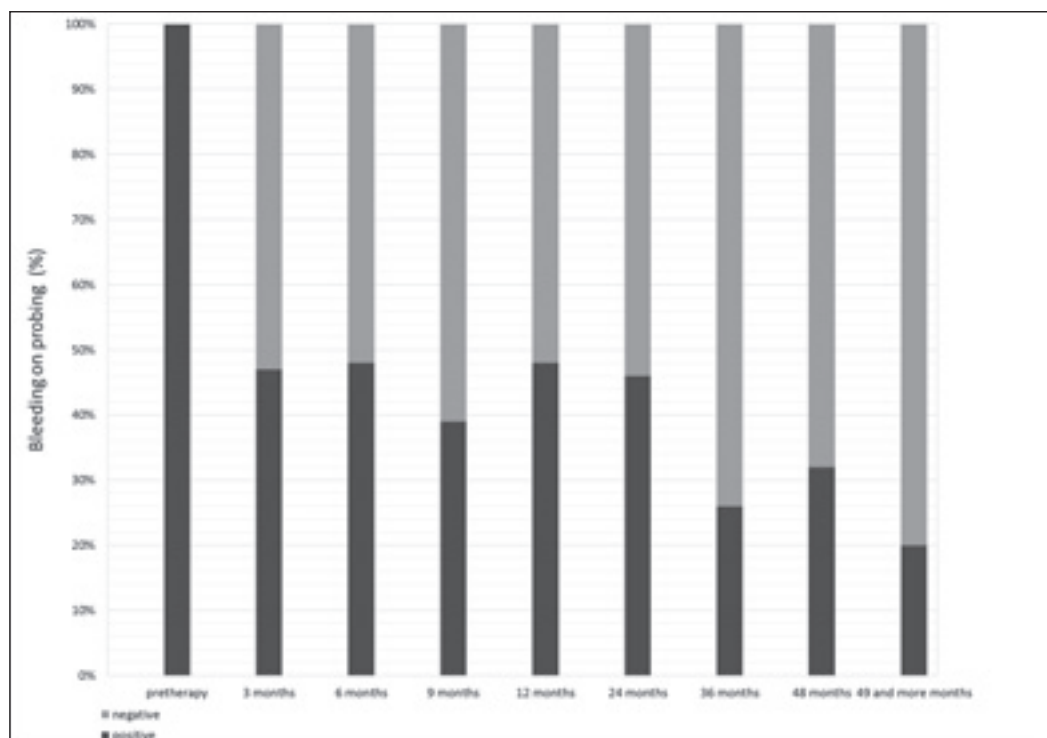


Fig. 7

after the periimplantitis therapy and in 73.1% of 26 implants evaluated with long-term data available 49–56 months post-therapy (**Fig. 7**).

During the follow-up period, one treated implant had to undergo additional gingivectomy and eight repeated implantoplasties. Despite treatment, 15 implants had to be explanted

during the follow-up period (9.49%), three of these in patients with diabetes, one in a smoker and two in which the therapy included an intraosseous defect treatment.

Evaluation of the original data files for the 158 treated implants established that bone augmentation procedures using a DBBM and an

Table 1

Implant system	Number of implants inserted	Number of explantations	% loss due to explantations
ANKYLOS	191	5	2.62
ASTRA TECH	1177	21	1.78
CAMLOG .Cylinder Line	4888	578	11.80
CAMLOG Screw Cylinder Line	1783	63	3.53
CAMLOG ROOT-LINE	289	21	7.27
CAMLOG SCREW-LINE	747	34	4.55
CAMLOG SCREW-LINE Promote plus	8014	105	1.31
CAMLOG iSy	62	2	3.23
Dentegris	6		0.00
FRIALIT 2	2042	234	11.50
IMZ TwinPlus	499	67	13.40
ITI	37	1	2.70
Nobel	11		0.00
Straumann	324	30	9.26
XiVE	2430	53	2.18
Others	155	15	9.68
Implant type not classified	69	10	14.50
Total	22724	1239	5.45

NBCM had been performed in 20 implants (12.7%) before or simultaneously with the implantation. Autologous bone had been used additionally for one of these. No initial augmentation had been performed in 127 implants (80.4%), while this information was not available for 11 implants (6.96%). The augmentation rate of all 22,724 implants inserted between 1993 and 2014 was 31%. In an additional subanalysis, for all 22,724 implants, the explantation rate was evaluated per implant system (**Table 1**). Of these, 1,239 implants were explanted owing to periimplantitis (5.45%). The highest rates of explantations were noted for the CAMLOG Cylinder Line, FRIALIT 2 and IMZ TwinPlus.

Statistical analysis of the null hypothesis of no association between indication class and the need for implant therapy applying the chi-squared test yielded a p -value of 0.0056. Thus, at the 5% level of significance, the hypothesis of no differences across indication classes with respect to the need for periimplantitis therapy might be withdrawn. Comparing the implant indication classes between all 22,724 implants and the 158 implants that underwent periimplantitis therapy, free-end situations (indication Class IIb) tended to be more frequent in the periimplantitis group ($p = 0.07$), while interden-

tal spaces (indication Class IIa) were significantly less frequent ($p = 0.02$). The frequencies of all other indication classes were not significantly different between all inserted implants and implants that underwent periimplantitis therapy (**Fig. 8**). However, in 2,728 of all 22,724 inserted implants (12%), the indication class could not be evaluated retrospectively.

Discussion

The retrospective evaluation presented here focused on the treatment of patients with implants placed between 1993 and 2014 in our practice and later treated again owing to periimplantitis. Of the implants that received periimplantitis therapy with or without GBR, treatment was successful in terms of stable reduction in PPD and BOP and implant survival of 90.5%, as only 15 of the 158 implants had to be extracted despite periimplantitis therapy over the observation period of our evaluation.

Our findings are in accordance with several reviews reporting successful surgical therapy of periimplantitis despite disease progression or recurrence.^{7,10,19,20} A recent meta-analysis compared the results for PPD reduction and radio-

Table 1

Distribution of implant systems: overall inserted implants and implants affected by periimplantitis between 1993 to 2014.

Fig. 8

Distribution per indication class at the time of implantation for implants treated for periimplantitis compared with all inserted implants. (All implants: $n = 22,724$; periimplantitis-affected implants: $n = 158$).

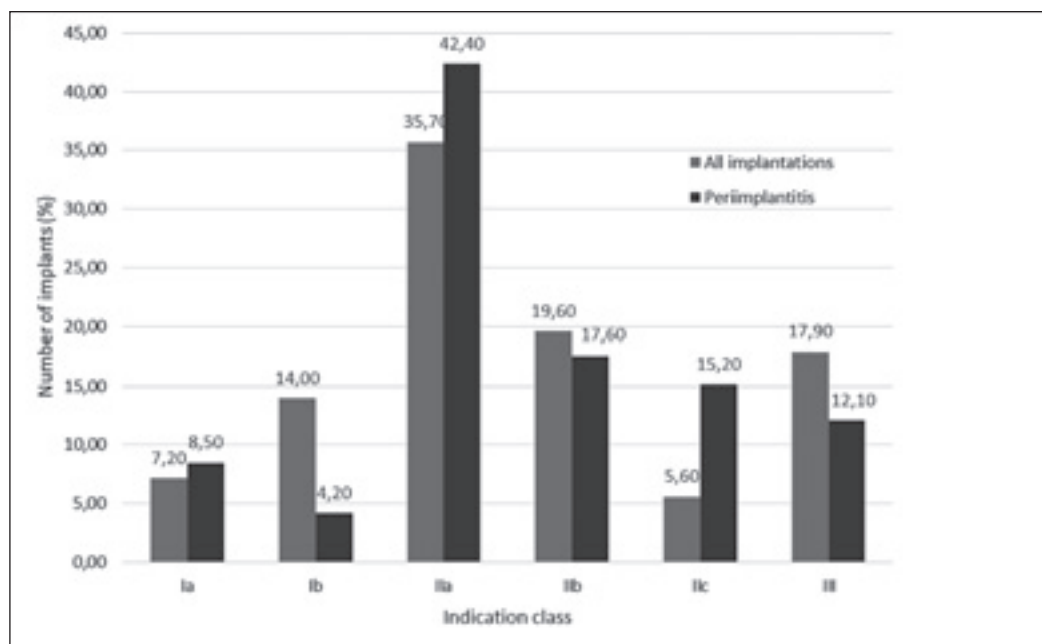


Fig. 8

graphic bone fill for different surgical approaches.¹⁹ Greater PPD reduction and radiographic bone fill were found when grafting materials and membranes were applied compared with procedures that used access flaps, debridement and resection. In another meta-analysis, greater PPD reduction and gain of clinical attachment were found when bone grafts and membranes were applied compared with a nonsurgical therapy.²¹ However, regenerative therapy has been shown to be more effective in contained, circumferential intrabony defects than in defects with buccal dehiscences or a predominantly suprabony component.¹¹ Therefore, in our evaluation, a treatment concept considering defect morphology according to the classification of Schwarz et al. was applied.^{17, 18} Interestingly, 36.1% of the implants with periimplantitis presented with a defect morphology allowing bone augmentation procedures. For financial reasons, in only 28.5% of the implants did periimplantitis therapy include bone augmentation. This included defect Classes Ib, c, d and e. The defect morphology of the remaining implants treated for periimplantitis corresponded to 55.0% Class II and 8.9% Class Ia defects. These defect types were therefore treated by anti-infective, resective therapy only.

For the regenerative treatment of intraosseous defects, we applied a DBBM and an NBCM. Our findings are in accordance with other reports that found encouraging results of periimplantitis treatment using a DBBM with or without an

NBCM. In a case series of 51 consecutively treated patients who presented with periimplantitis, Froum et al. used enamel matrix protein, a combination of a platelet-derived growth factor with anorganic bovine bone or mineralized freeze-dried bone and an NBCM.¹⁴ Bone level measured by periapical radiographs or bone sounding increased and remained stable up to 7.5 years after periimplantitis therapy. Positive results in terms of PPD reduction and radiographic bone fill after one year were also found using a DBBM and an NBCM in intrabony defects with a PPD > 5 mm.¹⁵ Using a DBBM, Aghazadeh et al. reported reduced PPD after 12 months and a higher likelihood of radiographic defect fill compared with autogenous bone.¹³ In two other studies, a significant defect reduction was achieved using a DBBM in implants with crater-like defects at the one-year follow-up.^{12, 16} These results, together with the data of our retrospective evaluation, demonstrate that periimplantitis treatment using a DBBM and an NBCM in defects with suitable defect morphologies may be clinically effective.

In our retrospective evaluation, only a quarter of the implants affected by periimplantitis underwent therapy while all other implants were regarded as hopeless and explanted. We support recommendations of other authors to include patients with implants in a strict maintenance program^{7, 8} as poor oral hygiene is a well-known risk factor for periimplantitis.⁶ However, this was probably not ensured in many of the cases

included in our evaluation, as almost half of the patients presented with generalized periodontitis at the start of the periimplantitis treatment. Therefore, periimplantitis may have proceeded in many implants to a stage that required explantation. In fact, a recent analysis demonstrated that implants provided with prostheses delivered by general practitioners were at higher risk of moderate and severe periimplantitis.²² Dentists who follow up on implant patients should be sensitized and should be instructed to establish strict maintenance programs according to consensus statements, especially regarding diagnosis of mucositis. Regular clinical monitoring with professional plaque removal and reinforcement of oral hygiene may also have been a main factor of the long-term success of the 158 implants that received periimplantitis therapy in our evaluation.

Simultaneous bone augmentation procedures at the time of implantation may bear higher risk of periimplantitis.^{23,24} The results of our retrospective evaluation, however, established that only 12.7% of the implants that received periimplantitis therapy had initially been inserted together with bone augmentation. Bone augmentation in all 22,724 inserted implants was 31%. The results indicate that implants in augmented sites are not more susceptible to periimplant infection than implants inserted without bone augmentation. Nevertheless, clear conclusions must first be drawn in clinical studies including both hopeless implants and implants suitable for periimplantitis therapy.

Various clinical studies have found smokers to be at higher risk of developing periimplant infections.^{6,25} A meta-analysis by Atieh et al. found a significantly higher frequency of periimplant disease in smokers (36%).² This is in accordance with the results of our retrospective evaluation, in which 16.8% of the patients who underwent periimplantitis therapy were smokers and 16.7% of the smokers had already undergone explantation and re-implantation previously. Uncontrolled diabetes and the intake of bisphosphonates are two additional risk factors for periimplantitis.^{6,25} In our retrospective evaluation, 4.67% of the patients were diabetic and 3.80% received bisphosphonates at the time of implantation. Lindhe et al. demonstrated that 5% of the patients that had undergone periimplantitis therapy and 23% of the patients in which explantations were performed despite the therapy had diabetes.⁶ These results support the conclusion that implant patients with

diabetes are at higher risk and should be informed accordingly. Similarly, bisphosphonates have been found to increase the risk of implant failure due to impaired implant osseointegration. However, a review has shown that successful long-term results of implant therapy can be achieved in patients despite bisphosphonate intake.²⁶ Our retrospective evaluation, however, does not provide a clear conclusion for negative effects of bisphosphonate intake or diabetes mellitus on the long-term survival of implants.

In an additional subanalysis, the overall explantation rate of implants placed between 1993 and 2014 was calculated to be 5.45%. Three implant systems presented with a failure rate of more than 10%. However, the number of periimplantitis patients who were not referred back and treated elsewhere is not known. Therefore, the analysis does not allow for definitive conclusions of the prevalence of periimplantitis affecting implants inserted in our practice.

Conclusion

In our retrospective evaluation, data from patients who were referred for periimplantitis treatment were analyzed. Using a treatment approach that included a hygiene phase and that considered defect morphology, PPD and BOP were improved and remained stable over more than four years post-therapy. Retreatments or explantations may be necessary and should be considered part of periimplantitis therapy. The results of our evaluation demonstrated that periimplantitis can be treated successfully and with good long-term results if a treatment approach is chosen based on defect morphology and on consensus recommendations and if patients are enrolled in a strict maintenance program. However, owing to the retrospective character of this evaluation, it is recommended that scientifically sound clinical trials be performed to further evaluate the efficacy of the periimplantitis treatment described here.

Competing interests

The expenses for statistical data analysis and description were covered by Geistlich Pharma, Wolhusen, Switzerland. Other than that, the authors declare that they have no competing interests.

References

1. Zitzmann NU, Berglundh T. Definition and prevalence of peri-implant diseases. → J Clin Periodontol. 2008 Sep;35(8 Suppl):286–91.
2. Atieh MA, Alsabeeha NH, Faggion CM Jr, Duncan WJ. The frequency of peri-implant diseases: a systematic review and meta-analysis. → J Periodontol. 2012 Nov;84(11):1586–98.
3. Mombelli A, Muller N, Cionca N. The epidemiology of peri-implantitis. → Clin Oral Implants Res. 2012 Oct;23 Suppl 6:67–76.
4. Derks J, Tomasi C. Peri-implant health and disease. A systematic review of current epidemiology. → J Clin Periodontol. 2015 Apr;42 Suppl 16:S158–71.
5. American Academy of Periodontology. Peri-implant mucositis and peri-implantitis: a current understanding of their diagnoses and clinical implications. → J Periodontol. 2013 Apr;84(4):436–43.
6. Lindhe J, Meyle J; Group D of the European Workshop on Periodontology. Peri-implant diseases: consensus report of the Sixth European Workshop on Periodontology. → J Clin Periodontol. 2008 Sep;35(8 Suppl):282–5.
7. Heitz-Mayfield LJ, Mombelli A. The therapy of peri-implantitis: a systematic review. → Int J Oral Maxillofac Implants. 2014;29 Suppl:325–45.
8. Heitz-Mayfield LJ, Needleman I, Salvi GE, Pjetursson BE. Consensus statements and clinical recommendations for prevention and management of biologic and technical implant complications. → Int J Oral Maxillofac Implants. 2014;29 Suppl:346–50.
9. Meyle J. Mechanical, chemical and laser treatments of the implant surface in the presence of marginal bone loss around implants. → Eur J Oral Implantol. 2012;5 Suppl:S71–81.
10. Renvert S, Polyzois I, Claffey N. Surgical therapy for the control of peri-implantitis. → Clin Oral Implants Res. 2012 Oct;23 Suppl 6:84–94.
11. Schwarz F, Sahm N, Schwarz K, Becker J. Impact of defect configuration on the clinical outcome following surgical regenerative therapy of peri-implantitis. → J Clin Periodontol. 2010 May;37(5):449–55.
12. Rocuzzo M, Bonino F, Bonino L, Dalmaso P. Surgical therapy of peri-implantitis lesions by means of a bovine-derived xenograft: comparative results of a prospective study on two different implant surfaces. → J Clin Periodontol. 2011 Aug;38(8):738–45.
13. Aghazadeh A, Rutger Persson G, Renvert S. A single-centre randomized controlled clinical trial on the adjunct treatment of intra-bony defects with autogenous bone or a xenograft: results after 12 months. → J Clin Periodontol. 2012 Jul;39(7):666–73.
14. Froum SJ, Froum SH, Rosen PS. Successful management of peri-implantitis with a regenerative approach: a consecutive series of 51 treated implants with 3- to 7.5-year follow-up. → Int J Periodontics Restorative Dent. 2012 Feb;32(1):11–20.
15. Matarasso S, Iorio Siciliano V, Aglietta M, Andreuccetti G, Salvi GE. Clinical and radiographic outcomes of a combined resective and regenerative approach in the treatment of peri-implantitis: a prospective case series. → Clin Oral Implants Res. 2014 Jul;25(7):761–7.
16. Rocuzzo M, Gaudio L, Lungo M, Dalmaso P. Surgical therapy of single peri-implantitis intrabony defects, by means of deproteinized bovine bone mineral with 10% collagen. → J Clin Periodontol. 2016 Mar;43(3):311–8.
17. Schwarz F, Herten M, Sager M, Bieling K, Sculean A, Becker J. Comparison of naturally occurring and ligature-induced peri-implantitis bone defects in humans and dogs. → Clin Oral Implants Res. 2007 Apr;18(2):161–70.
18. Schwarz F, Sahm N, Iglhaut G, Becker J. Impact of the method of surface debridement and decontamination on the clinical outcome following combined surgical therapy of peri-implantitis: a randomized controlled clinical study. → J Clin Periodontol. 2011 Mar;38(3):276–84.
19. Chan HL, Lin GH, Suarez F, MacEachern M, Wang HL. Surgical management of peri-implantitis: a systematic review and meta-analysis of treatment outcomes. → J Periodontol. 2014 Aug;85(8):1027–41.
20. Figuero E, Graziani F, Sanz I, Herrera D, Sanz M. Management of peri-implant mucositis and peri-implantitis. → Periodontol 2000. 2014 Oct;66(1):255–73.
21. Faggion CM Jr, Chambrone L, Listl S, Tu YK. Network meta-analysis for evaluating interventions in implant dentistry: the case of peri-implantitis treatment. → Clin Implant Dent Relat Res. 2013 Aug;15(4):576–88.
22. Derks J, Schaller D, Hakansson J, Wennstrom JL, Tomasi C, Berglundh T. Effectiveness of implant therapy analyzed in a Swedish population: prevalence of peri-implantitis. → J Dent Res. 2016 Jan;95(1):43–9.
23. Karbach J, Callaway A, Kwon YD, d'Hoedt B, Al-Nawas B. Comparison of five parameters as risk factors for peri-mucositis. → Int J Oral Maxillofac Implants. 2009 May-Jun;24(3):491–6.
24. Canullo L, Tallarico M, Radovanovic S, Delibasic B, Covani U, Rakic M. Distinguishing predictive profiles for patient-based risk assessment and diagnostics of plaque induced, surgically and prosthetically triggered peri-implantitis. → Clin Oral Implants Res. 2016 Oct;27(10):1243–50.
25. Turri A, Rossetti PH, Canullo L, Grusovin MG, Dahlin C. Prevalence of peri-implantitis in medically compromised patients and smokers: a systematic review. → Int J Oral Maxillofac Implants. 2016 Jan-Feb;31(1):111–8.
26. Javed F, Almas K. Osseointegration of dental implants in patients undergoing bisphosphonate treatment: a literature review. → J Periodontol. 2010 Apr;81(4):479–84.
27. Schwarz F, Sahm N, Becker J. Impact of the outcome of guided bone regeneration in dehiscence-type defects on the long-term stability of peri-implant health: clinical observations at 4 years. → Clin Oral Implants Res. 2012 Feb;23(2):191–6.

Celebrate World Oral Health Day on 20 March

HELP YOUR PATIENTS *Live* MOUTH SMART



Download **campaign resources**

including brochure, posters, social media material
and more, to promote good oral health through life.

www.worldoralhealthday.org



Media Partner



Official Global Partners



Supporter



Bone augmentation of canine frontal sinuses using a porous α -tricalcium phosphate for implant treatment

Abstract

Objective

Compared with hydroxyapatite, alpha-tricalcium phosphate (α -TCP) is more biodegradable and shows better integration during physiological bone remodeling. The objective of this study was to evaluate the effects of porous α -TCP as a tissue-engineered scaffold for maxillary sinus augmentation in a canine model.

Materials and methods

Porous α -TCP was prepared by pulverizing an α -TCP block with an 80% continuous pore structure. Bilateral sinus floor augmentation surgeries were performed on beagle dogs that were randomly divided into two groups based on the type of repair: The experimental group received a porous α -TCP and titanium (Ti) implant, and the control group received a Ti implant. Periimplant bone volume (BV) and bone mineral content (BMC) were measured and analyzed using micro-computed tomography (micro-CT) and Villanueva–Goldner staining for histological examination. The intergroup differences were evaluated using the Student's *t*-test.

Results

Micro-CT images at 12 weeks after surgery showed higher BV and BMC in the experimental group than in the control group ($p < 0.05$). Histological examination showed high levels of α -TCP even at four weeks, but the scaffolds were completely absorbed and new bone integrated into the Ti implants at 12 and 24 weeks. However, no bone formation was observed in the control group throughout the study.

Conclusion

Porous α -TCP increased BV and promoted bone mineralization and earlier bone formation in the augmented maxillary sinus. Therefore, this tissue-engineered scaffold might be a better alternative to autologous bone for maxillary sinus augmentation.

Keywords

Bone augmentation, porous α -tricalcium phosphate, canine frontal sinuses.

Masataka Hirose,^a Naoya Uemura,^a Yoshiya Hashimoto,^b Isumi Toda^c & Shunsuke Baba^a

^a Department of Oral Implantology, Osaka Dental University, Hirakata, Japan

^b Department of Biomaterials, Osaka Dental University, Hirakata, Japan

^c Department of Anatomy, Osaka Dental University, Hirakata, Japan

Corresponding author:

Dr. Yoshiya Hashimoto

Department of Biomaterials
Osaka Dental University, 8-1
Kuzuhahanazono-cho Hirakata
5731121 Osaka
Japan

yoshiya@cc.osaka-dent.ac.jp

How to cite this article:

How to cite this article: Hirose M, Uemura N, Hashimoto Y, Toda I, Baba S. Bone augmentation of canine frontal sinuses using a porous α -tricalcium phosphate for implant treatment.

J Oral Science Rehabilitation.
2017 Mar;3(1):44–51.

Introduction

Implant placement in highly atrophic maxillae has been a major challenge in implant dentistry. Sinus floor elevation is a preferred option in such situations. Various maxillary sinus floor augmentation techniques have been developed for managing severe bone loss in the maxilla.^{1–4} However, it is important to define the best bone substitute for the subsinus cavity after sinus membrane lift procedures. Although autogenous bone grafting is still considered the gold standard for treatment, it has several disadvantages, including the requirement of a second surgery at the donor site and limited bone supply.^{5,6} Artificial bone grafts are promising alternatives to autogenous bone grafts.

Synthetic hydroxyapatite (HA) has been widely applied in the medical and dental fields because of its high biocompatibility and osteoconductive properties.^{7,8} However, the application of HA has to be carefully considered because it is poorly displaced by new bone tissue⁹ and is easily adsorbed by bacteria and epithelial cells because of its high surface energy.^{10,11} Bovine HA is frequently used as a grafting material in sinus lift procedures because of its features that resemble cancellous bone, complete deproteinization of the inorganic component and thus the absence of antigenicity.¹² Beta-tricalcium phosphate (β -TCP) was one of the earliest calcium phosphate compounds used as a bone graft substitute because of its high osteoconductivity, tissue compatibility and ability to withstand sufficient mechanical stress.¹³ High-temperature TCP, known as α -TCP, is often prepared by sintering amorphous precursors with the proper composition.¹⁴

Marukawa et al. demonstrated the usefulness of self-setting α -TCP (BIOPEX-R) in maintaining the rigidity of implanted bone screws using maxillary sinus augmentation in rabbits.¹⁵ However, a drawback of self-setting bone cement is its weak mechanical property. In a previous study, we fabricated porous α -TCP composites with a continuous small-and-large-pore structure and demonstrated that the composite created using porous α -TCP particles and collagen or collagen model peptide had enough adaptability for treating skull bone defects in miniature pigs.⁵ However, the effectiveness of porous α -TCP particles as a grafting material in sinus lift procedures has not yet been investigated. The objective of this study was to evaluate the effects of porous α -TCP as a tissue-engineered scaffold using a canine frontal sinus model.

Materials and methods

Material analysis

Preparation and characterization of porous α -TCP particles

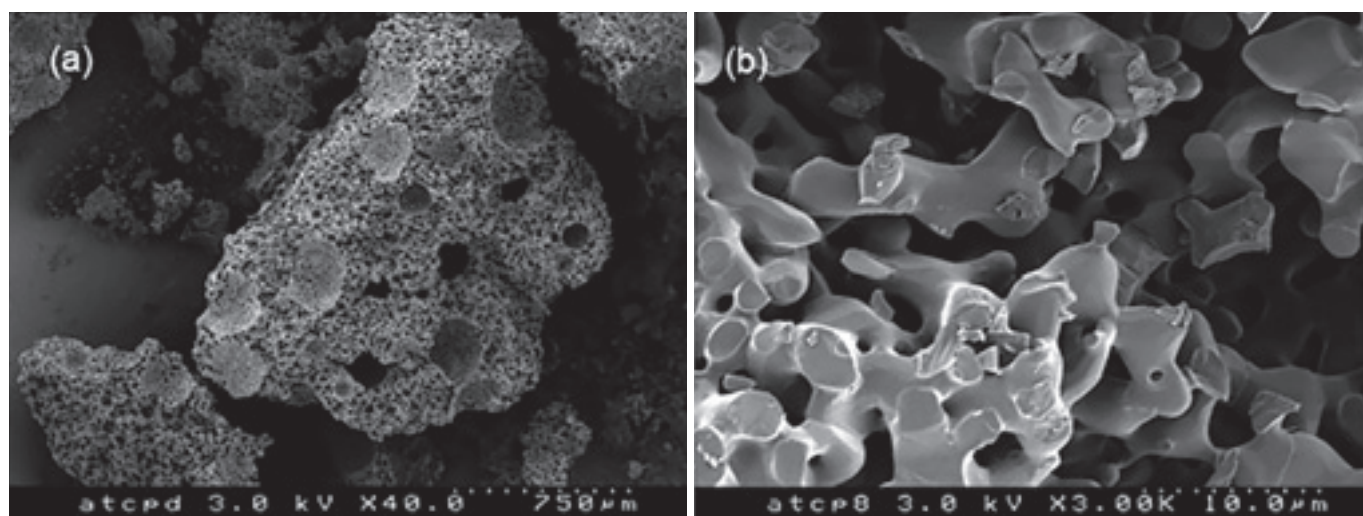
Porous α -TCP particles with an average diameter of 580.8 μm and porosity of about 80% were obtained from Taihei Chemical Industrial (Osaka, Japan) and sterilized by dry heating before the experiment. A field-emission scanning electron microscope (S-4100, Hitachi High-Technologies Corporation, Tokyo, Japan) was used to analyze particle size, pore distribution and outer surface conditions. Before observation, samples were coated with platinum–palladium using the E-1030 (Hitachi High-Technologies Corporation). α -TCP particles were characterized using a powder X-ray diffraction system (XRD; XRD-6100, Shimadzu, Kyoto, Japan). XRD patterns were obtained with the following parameters: 40 kV, 30 mA, scan rate of 2°/min and step size of 0.05° within a range of 10–60°. Crystal phase was characterized using data from the International Centre for Diffraction Data (HA: 9-0432; α -TCP: 9-0348). X-ray photoelectron spectroscopy (XPS) measurements were performed to determine the surface Ca/P atomic ratios with a PHI X-tool (Ulvac-Phi, Chigasaki, Japan) equipped with an Al-K α radiation source (15 kV; 53 W; spot size of 205 μm) at a pass energy of 280.0 eV, a step size of 0.1 eV and a takeoff angle of 45° with 20 scans.

Animal models

The mandibular defect model was established using six healthy beagles (2 years old; weighing approximately 10 kg) obtained from Hamaguchi Animal (Osaka, Japan). The animals were housed in a temperature-controlled environment at 24 °C with free access to food and water. The body weight and general health of the animals were monitored throughout the study.

α -TCP particle transplantation

The dogs underwent bilateral sinus floor augmentation surgeries and were randomly divided into two groups depending on the type of repair: The experimental group received a porous α -TCP and tapered titanium (Ti) implant (NovelActive, Nobel Biocare Japan, Tokyo, Japan), and the control group received the



Figs. 1a & b

Figs. 1a & b

Scanning electron micrograph of porous α -TCP particles:

- (a) low-magnification image;
(b) high-magnification image.

Ti implant alone. All procedures in this study were approved by the Animal Experiment Committee of Osaka Dental University and conformed to the Guiding Principles for the Use of Laboratory Animals (approval No. 14-03015). Aseptic surgery was performed under general anesthesia (0.5 mg/kg pentobarbital sodium) with physiological saline cooling and infiltration anesthesia (1.8 mL of 2% lidocaine hydrochloride and 1:80,000 epinephrine). The hair from the frontal region was removed, and the skin including the frontal sinus was incised in the shape of an arc. The skin–periosteal flap was detached, and the anterior wall of the frontal sinus was exposed. Then, an approximately 10 mm wide rectangular opening was made in the anterior wall of the left and right frontal sinuses using a twist drill (Astra Tech, Tokyo, Japan). In addition, porous α -TCP particles (2.7 cm³) were filled in this elevation space. The Ti implant was embedded at a distance of about 5 mm from the bony window. The anti-inflammatory agent carprofen (Carprodyl VR, Ceva, Libourne, France) was administered daily for seven days after the surgery.

Radiographic analysis

The maxillae were harvested for examination by micro-computed tomography (micro-CT; SMX-130CT, Shimadzu). Blocks of bone specimens were mounted on the turntable and scanned at 105 kV and 30 μ A. TRI/3D-BON software (RATOC System Engineering, Tokyo, Japan) was used to generate a 3-D reconstruction using the volume-rendering method for morphological assessment. In the 3-D analysis, bone volume (BV in mm³) and bone mineral content (BMC in

mg) were measured using the TRI/3D-BON software based on the values obtained.

Histological assessment

After fixation with 10% phosphate-buffered formalin, the specimens with the Ti implant were dehydrated in ethanol and then embedded in acrylic resin (Technovit 7200 VLC, Heraeus Kulzer, Wehrheim, Germany). The embedded blocks were trimmed using a cutter and ground using abrasive paper. Thereafter, the sections were further ground to a final thickness of about 30 μ m. Finally, the specimens were stained with the Villanueva–Goldner stain and examined under a microscope.

Results

Characterization of α -TCP particles

Figure 1 shows the electron micrographs of α -TCP particles. At low magnification, the α -TCP particles had an amorphous body with many small and large pores (**Fig. 1a**). At high magnification, the α -TCP particles had smooth surfaces with a pore diameter of approximately 5–10 μ m. The XRD profiles of both intact particles are shown in **Figure 1b**. The specific peaks of α -TCP (indicated by the triangles) were detectable in the XRD patterns of both particles (**Fig. 2**). For XPS, quantitative data of the atom% were obtained from the peak areas derived for O1s, Ca2p, P2p and C1s, from which the Ca/P ratio was calculated and found to be 1.5 (**Fig. 3**).

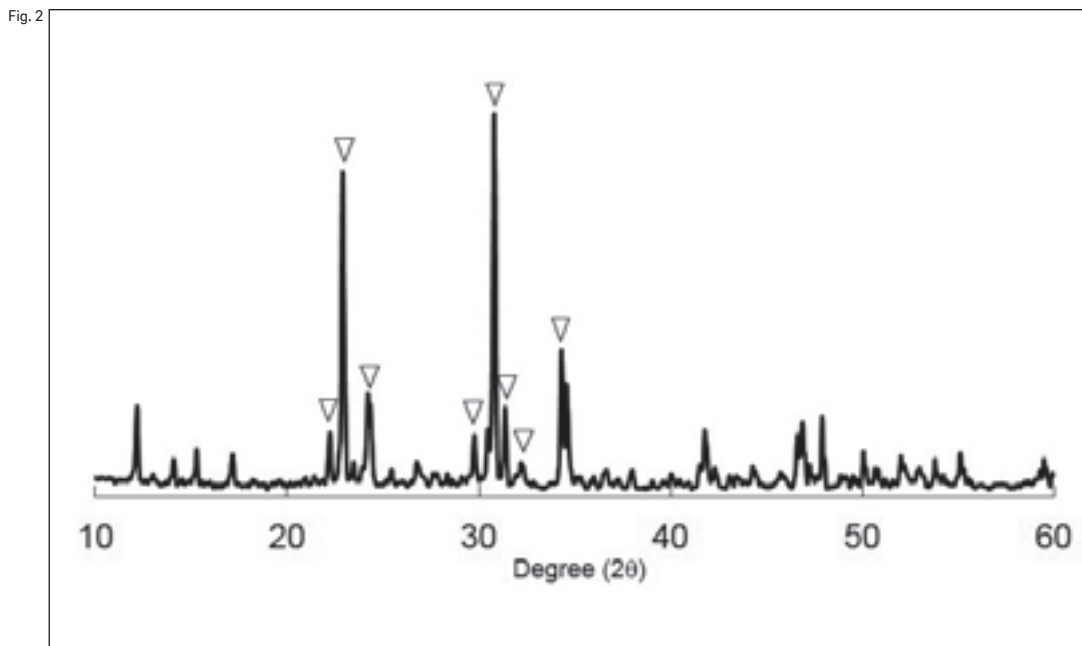


Fig. 2

XRD pattern of porous α -TCP particles. Triangles show α -TCP peaks.

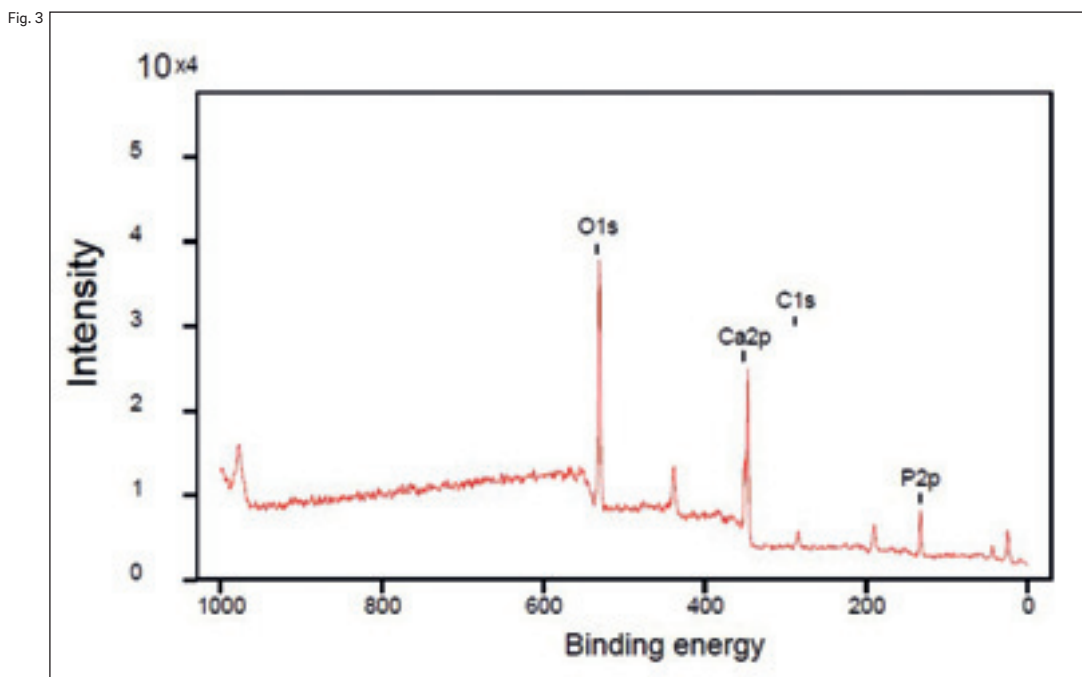


Fig. 3

Wide X-ray photoelectron spectra of porous α -TCP particles.

Radiographic analysis

A quantitative imagology analysis of the bone window areas of the specimens was carried out at four, 12 and 24 weeks using micro-CT (**Fig. 4**). In the experimental group, newly formed bone was observed in the area of the bone window; however, bone formation reduced between 12 and 24 weeks. In the control group, the area of the bone window was empty, although some new bone formation was observed toward the edges of the bone window.

BV and BMC analysis

BV and BMC of each group were determined at four, 12 and 24 weeks (**Fig. 5**). BV and BMC were higher in the experimental group than in the control group at 12 weeks ($p < 0.05$). No significant intergroup differences were observed in either analysis at four or 24 weeks ($p > 0.05$; **Fig. 5**).

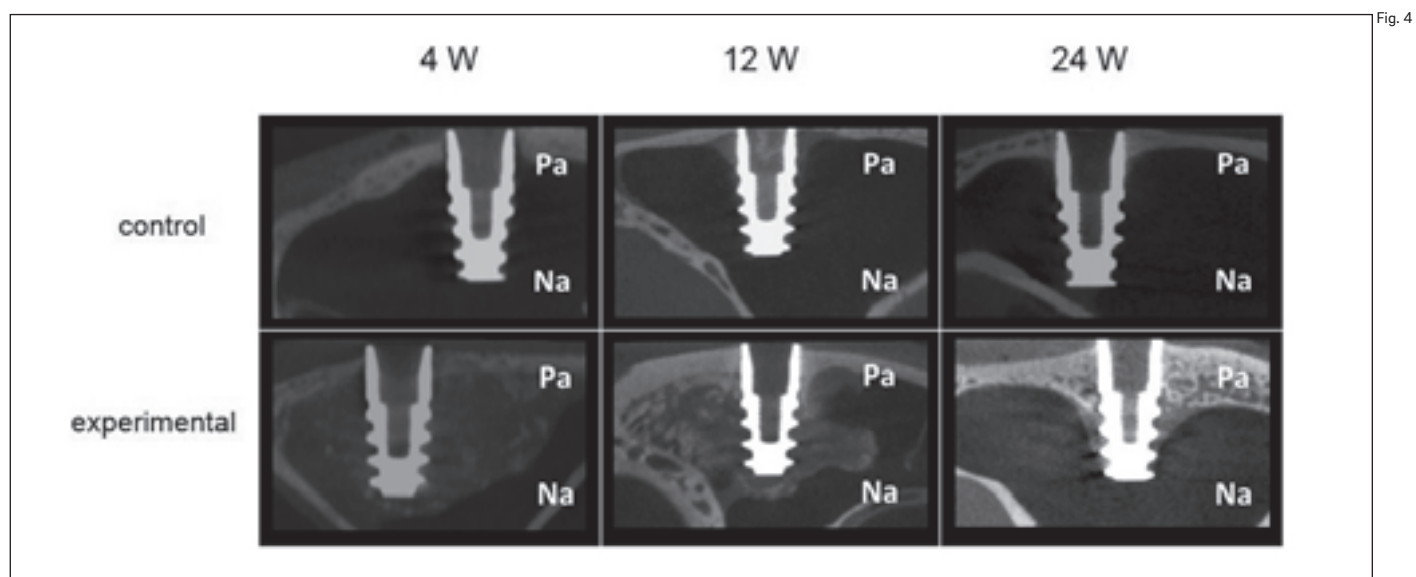


Fig. 4

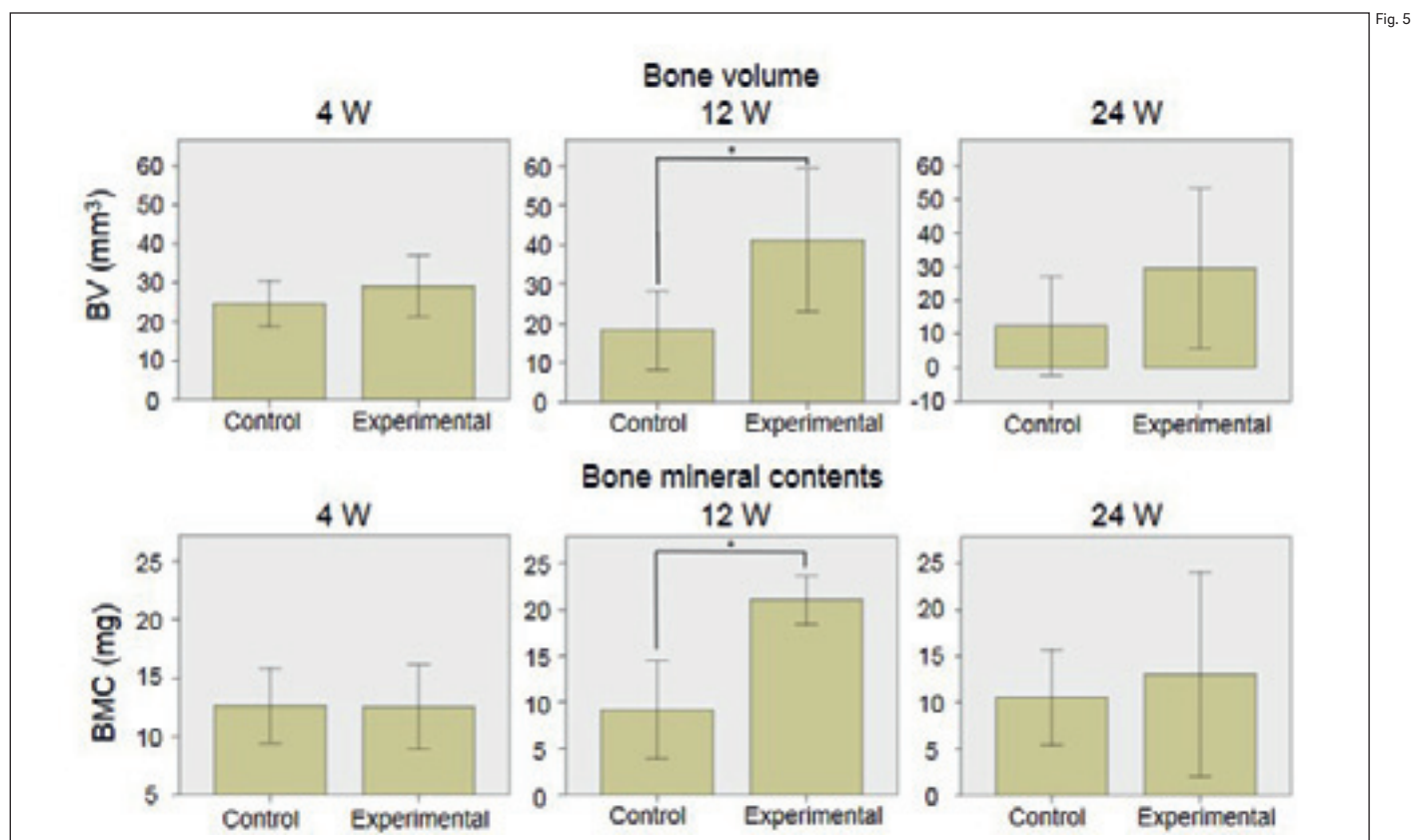


Fig. 5

Fig. 4

Micro-CT images acquired at four, 12 and 24 weeks after surgery. (PA = palatal side; NA = nasal side).

Fig. 5

The upper and lower groups show BV (mm³) and BMC (mg) of each group, reflecting the quantity of new bone at four, 12 and 24 weeks after surgery.

Histological assessment

Histological assessments were also performed at four, 12 and 24 weeks (**Figs. 6 & 7**). Histological images showed high levels of porous α -TCP even at four weeks; however, the scaffolds had completely absorbed and new bone integrated into the Ti implants at 12 and 24 weeks. The

formation of new bone in the area of the bone window reduced between 12 and 24 weeks; however, the newly formed bone had changed to mature bone (**Fig. 6**). Although no bone formation was observed in the control group throughout the study, some new bone formation was observed toward the edges of the bone window (**Fig. 7**).

Fig. 6

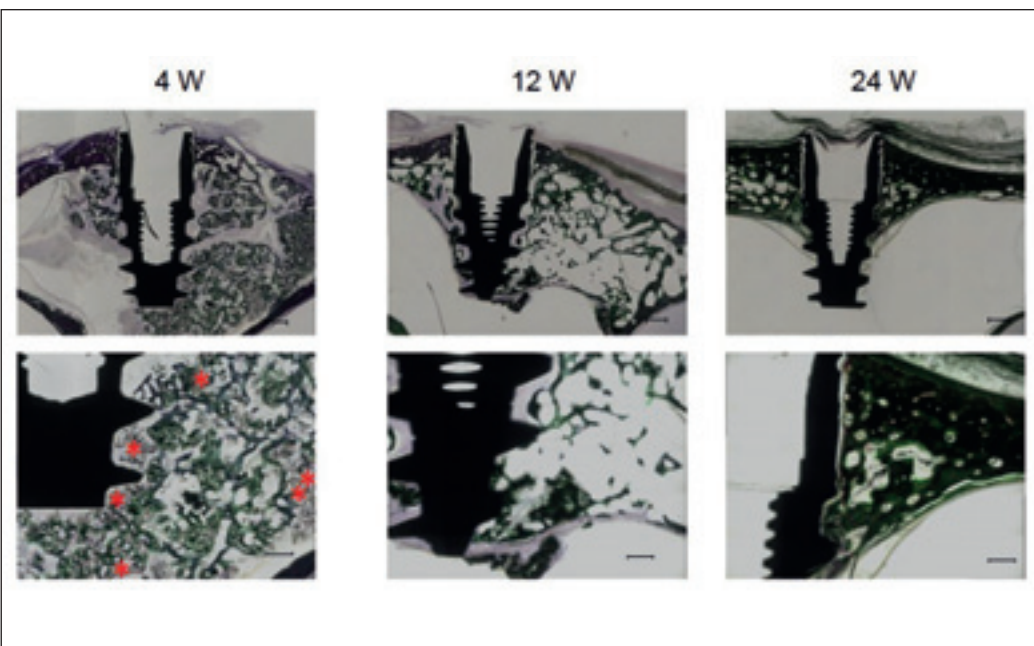


Fig. 6

Low- and high-magnification images in the experimental group, demonstrating new bone formation in the upper and lower groups at 4, 12 and 24 weeks after surgery. Red asterisks show the residual porous α -TCP particles. Each black bar of the low- and high-magnification images shows 1,000 and 500 μ m, respectively.

Fig. 7

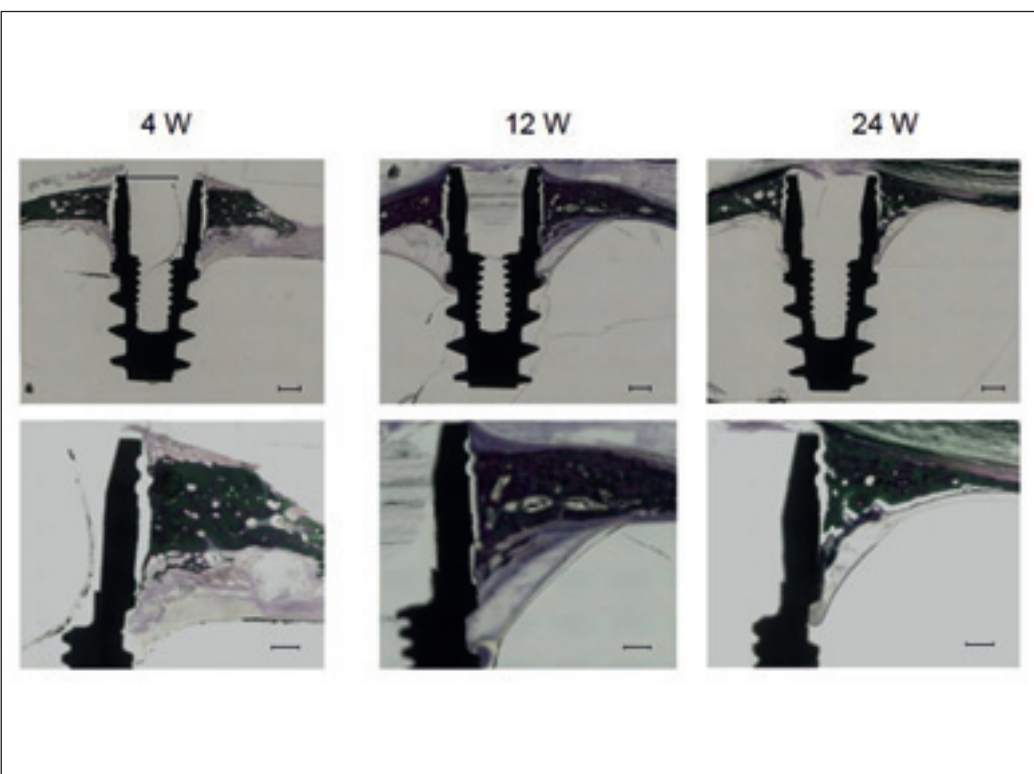


Fig. 7

The low- and high-magnification images in the control group, demonstrating new bone formation in the upper and lower groups at 4, 12 and 24 weeks after surgery. Each black bar of the low- and high-magnification images shows 1,000 and 500 μ m, respectively.

Discussion

α -TCP is widely considered an option for use as a bone grafting material. However, few studies have used porous α -TCP particles for sinus lift with tissue engineering techniques. In order to maximize the surface area for cell attachment and proliferation, we fabricated the scaffold into

a highly porous 3-D structure through a relatively simple processing method involving a conventional sintering procedure. Previous studies have used a slurry of β -TCP and potato starch to produce α -TCP that was in a thermodynamically stable phase at temperatures above 1,100 °C.¹⁶ Uchino et al. found that HA formation is rarely observed on the surface of porous α -TCP

ceramics with 80% porosity.¹⁷ In this study, a comparison of the scatter plot data of the synthesized α -TCP particles with that of α -TCP data registered with the Joint Committee on Powder Diffraction Standards confirmed that these peaks appeared at the same angles. In addition, the Ca/P ratio of the product was 1.5, which fulfilled the requirements of the ASTM standards.¹⁸

Basic animal research on sinus lift has been conducted on dogs, sheep and rabbits.^{12,19,20} The canine frontal sinus is a size closer to the human maxillary sinus and allows accurate control of a large number of experimental models. In addition, the canine frontal sinus is the largest among the canine paranasal sinuses and the canine sinus wall is covered with multiple rows of ciliated columnar epithelium, as is the human maxillary sinus.²¹ Moreover, the surgeon can approach both sides of the frontal sinus through a single incision because the left and right frontal sinuses are adjacent to each other.

In the edentulous jaw and sinus-alveolar crest, the distance between the sinus and the alveolar bone is important in terms of implant treatment. A bone height of around 20 mm is required for dental implant treatment; therefore, sinus surgery is expected to promote bone formation to a height of more than 20 mm.²² Since the vertical length of the human maxillary sinus is about 28 mm, the top of the implant projects from the maxillary sinus floor into the elevation space of 20 mm.²¹ In this experiment, the top of the implant projected into the canine frontal sinuses. Therefore, the canine frontal sinus was considered a suitable experimental model of sinus surgery.

The biological behavior of α -TCP-based biomaterials has been analyzed in several *in vivo* studies.^{23–25} Kihara et al. performed an *in vivo* test using a rat model to observe the biodegradation process of particles (~300 μ m diameter) of pure α -TCP and found that the residual α -TCP particles degraded without decreasing the volume of the transplantation region.²⁶ Our previous study evaluated the effects of combining poly(Pro-Hyp-Gly) and α -TCP particles on bone formation in a canine tibial defect model.²³ These particles did not induce inflammation; moreover, complete degradation and remodeling of the lamellar bone were observed with their use. This, to our knowledge, is the first study to investigate the effects of porous α -TCP as a tissue-engineered scaffold for maxillary sinus augmentation in a canine model. Although histological images showed high levels of porous

α -TCP at four weeks, new bone formation had already started. Moreover, the porous α -TCP particles had been completely absorbed and replaced with new bone at 12 weeks. New bone formation in the area of the bone window reduced between 12 and 24 weeks. No bone exists originally in the area of the bone window; thus, the newly formed bone will be absorbed over time. Mechanical stresses, such as occlusion, may inhibit the absorption of the newly formed bone. Although β -TCP was an acceptable bone substitute material for augmenting maxillary sinus bone formation, it was likely to continue increasing and would have been progressively replaced over a longer time.²⁷ However, prolonged bone augmentation is disadvantageous.

Conclusion

Sinus floor augmentation is a safe and elegant surgical procedure before implant insertion. The porous α -TCP tested is a biocompatible, osteoconductive material that promotes new bone formation when used with integrated Ti implants, as demonstrated in this study on a canine frontal sinus model. However, the effectiveness and safety of this method need to be further evaluated before it can be clinically applicable.

Competing interests

The authors declare no conflicts of interest.

Acknowledgments

This work was funded by the Promotion and Mutual Aid Corporation for Private Schools of Japan's Science Research Promotion Fund (Tokyo, Japan; No. 15-09).

References

- Acocella A, Bertolai R, Nissan J, Sacco R. Clinical, histological and histomorphometrical study of maxillary sinus augmentation using cortico-cancellous fresh frozen bone chips.
→ J Craniomaxillofac Surg.
2011 Apr;39(3):192–9.
- Summers RB. A new concept in maxillary implant surgery: the osteotome technique.
→ Compendium.
1994 Feb;15(2):152, 154–6, 158 passim; quiz 162.
- Wetzel AC, Stich H, Caffesse RG. Bone apposition onto oral implants in the sinus area filled with different grafting materials. A histological study in beagle dogs.
→ Clin Oral Implants Res.
1995 Sep;6(3):155–63.
- Zhang Y, Tangl S, Huber CD, Lin Y, Qiu L, Rausch-Fan X. Effects of Choukroun's platelet-rich fibrin on bone regeneration in combination with deproteinized bovine bone mineral in maxillary sinus augmentation: a histological and histomorphometric study.
→ J Craniomaxillofac Surg.
2012 Jun;40(4):321–8.
- Sakai K, Hashimoto Y, Baba S, Nishiura A, Matsumoto N. Effects on bone regeneration when collagen model polypeptides are combined with various sizes of alpha-tricalcium phosphate particles.
→ Dent Mater J.
2011 Nov;30(6):913–22.
- Weiland AJ, Phillips TW, Randolph MA. Bone grafts: a radiologic, histologic, and biomechanical model comparing autografts, allografts, and free vascularized bone grafts.
→ Plast Reconstr Surg.
1984 Sep;74(3):368–79.
- Goto T, Kojima T, Iijima T, Yokokura S, Kawano H, Yamamoto A, Matsuda K. Resorption of synthetic porous hydroxyapatite and replacement by newly formed bone.
→ J Orthop Sci.
2001 Jun;6(5):444–7.
- Velich N, Németh Z, Hrabák K, Suba Z, Szabó G. Repair of bony defect with combination biomaterials.
→ J Craniofac Surg.
2004 Jun;15(1):11–5.
- Yamada K, Umeda M, Komori T, Kawai T. Influence of hydroxyapatite (HA) chemical composition on solubility behavior and bone formation.
→ Kokubyo Gakkai Zasshi.
2001 Jun;50(2):90–7.
- Chidylo SA, Marschall MA. Porous hydroxyapatite and tissue infection.
→ Plast Reconstr Surg.
1992 Jun;90(1):146–7.
- Rosen HM. The response of porous hydroxyapatite to contiguous tissue infection.
→ Plast Reconstr Surg.
1991 Dec;88(6):1076–80.
- Haas R, Donath K, Födinger M, Watzek G. Bovine hydroxyapatite for maxillary sinus grafting: comparative histomorphometric findings in sheep.
→ Clin Oral Implants Res.
1998 Apr;9(2):107–16.
- Matsuno T, Nakamura T, Kuremoto K, Notazawa S, Nakahara T, Hashimoto Y, Satoh T, Shimizu Y. Development of beta-tricalcium phosphate/collagen sponge composite for bone regeneration.
→ Dent Mater J.
2006 Mar;25(1):138–44.
- Carrodeguas R, De Aza S. α -Tricalcium phosphate: synthesis, properties and biomedical applications.
→ Acta Biomater.
2011 Oct;7(10):3536–46.
- Marukawa K, Ueki K, Okabe K, Nakagawa K, Yamamoto E. Use of self-setting α -tricalcium phosphate for maxillary sinus augmentation in rabbit.
→ Clin Oral Implants Res.
2011 Jun;22(6):606–12.
- Kitamura M, Ohtsuki C, Iwasaki H, Ogata SI, Tanihara M, Miyazaki T. The controlled resorption of porous α -tricalcium phosphate using a hydroxypropylcellulose coating.
→ J Mater Sci Mater Med.
2004 Oct;15(10):1153–8.
- Uchino T, Ohtsuki C, Kamitakahara M, Tanihara M, Miyazaki T. Apatite formation behavior on tricalcium phosphate (TCP) porous body in a simulated body fluid.
→ Key Eng Mater.
2006 Jun;309–11:251–4.
- Carrodeguas RG, De Aza S. α -Tricalcium phosphate: synthesis, properties and biomedical applications.
→ Acta Biomater.
2011 Oct;7(10):3536–46.
- Jeong SM, Lee CU, Son JS, Oh JH, Fang Y, Choi BH. Simultaneous sinus lift and implantation using platelet-rich fibrin as sole grafting material.
→ J Craniomaxillofac Surg.
2014 Sep;42(6):990–4.
- Watanabe K, Niimi A, Ueda M. Autogenous bone grafts in the rabbit maxillary sinus.
→ Oral Surg Oral Med Oral Pathol Oral Radiol Endod.
1999 Jul;88(1):26–32.
- Shimizu H, Watanabe T, Sato J. [An animal experiment using dog frontal sinuses for histological consideration of the maxillary sinus augmentation surgery for implants].
→ Tsurumi Shigaku.
2003 Jan;29(1):37–56. Japanese.
- Tatum OH Jr, Lebowitz MS, Tatum CA, Borgner R. Sinus augmentation. Rationale, development, long-term results.
→ N Y State Dent J.
1993 May;59(5):43–8.
- Ito T, Hashimoto Y, Baba S, Iseki T, Morita S. Bone regeneration with a collagen model polypeptides/ α -tricalcium phosphate sponge in a canine tibia defect model.
→ Implant Dent.
2015 Apr;24(2):197–203.
- Li P, Hashimoto Y, Honda Y, Nakayama Y, Kobayashi N, Hara E, Yasui K, Arima Y, Matsumoto N. Evaluation of bone regeneration by porous alpha-tricalcium phosphate/atelocollagen sponge composite in critical-sized rat calvarial defects.
→ J Hard Tissue Biol.
2016 Jun;25(1):35–40.
- Tokuda T, Honda Y, Hashimoto Y, Matsumoto N. Comparison of the bone forming ability of different sized-Alpha tricalcium phosphate granules using a critical size defect model of the mouse calvaria.
→ Nano Biomed.
2015 Dec;7(2):63–71.
- Kihara H, Shiota M, Yamashita Y, Kasugai S. Biodegradation process of α -TCP particles and new bone formation in a rabbit cranial defect model.
→ J Biomed Mater Res B Appl Biomater.
2006 Nov;79(2):284–91.
- Zerbo IR, Zijderveld SA, De Boer A, Bronckers AL, De Lange G, Ten Bruggenkate CM, Burger EH. Histomorphometry of human sinus floor augmentation using a porous β -tricalcium phosphate: a prospective study.
→ Clin Oral Implants Res.
2004 Dec;15(6):724–32.

Importance of a preoperative radiographic scale for evaluating surgical difficulty of impacted mandibular third molar extraction

Abstract

Objective

The objectives of the study were to evaluate the correlation between the degree of surgical difficulty measured by an established scale and the total surgical time, the ostectomy time and the tooth sectioning time, and to analyze which of the factors involved had a greater influence on total surgical time.

Materials and methods

A presurgical radiographic scale was developed, based on ten parameters. Each parameter was scored from 1 to 3, and the individual scores were summed. A retrospective analysis using panoramic radiographs was performed of patients subjected to surgical extraction of a mandibular third molar, with recording of the surgical times. A statistical analysis was performed to establish correlations between the study parameters and scale and the surgical times.

Results

A greater Winter's distance prolonged ostectomy time and, conversely, a greater distance from the mandibular ramus to the distal surface of the second molar was observed to shorten ostectomy time. Separate or dysmorphic root shape increased ostectomy time and total surgical time. Total surgical time was longer in the presence of greater coronal width and a shorter distance from the ramus to the second molar. The only variable correlated to tooth sectioning time was coronal width.

Conclusion

The final score was correlated to ostectomy time and total surgical time. Ostectomy time in turn was influenced by Winter's distance, the distance from the mandibular ramus to the second molar, and root shape. Tooth sectioning time was influenced by the coronal width of the third molar. The parameters with the closest correlation to total surgical time were coronal width and the distance between the ramus and second molar.

Keywords

Third molar surgery, wisdom teeth, impacted mandibular third molar, third molar extraction.

Natalia Ribes Lainez,^a José Carlos Sanchis González^a,
David Peñarrocha Oltra^a & José María Sanchis Bielsa^{a,b}

^a Department of Stomatology, Faculty of Medicine and
Odontology University of Valencia, Valencia, Spain

^b Department of Stomatology and Maxillofacial Surgery,
General University Hospital of Valencia, Spain

Corresponding author:

Dr. David Peñarrocha Oltra

Cirugía Bucal. Clínicas Odontológicas
C/Gascó Oliag, 1
46021 Valencia
Spain

T +34 963 86 4144
david.penarrocha@uv.es

How to cite this article:

How to cite this article: Ribes Lainez N, Sanchis González JC, Peñarrocha Oltra D, Sanchis Bielsa JM. Importance of a preoperative radiographic scale for evaluating surgical difficulty of impacted mandibular third molar extraction. J Oral Science Rehabilitation. 2017 Mar;3(1):52–9.

Introduction

A number of classification systems have been proposed for estimating the surgical difficulty of impacted mandibular third molar extraction, based on preoperative assessment of panoramic radiographs. The traditional classifications are those of Pell and Gregory¹ and Winter,² based on the depth of the third molar, the relation to the mandibular ramus and the anatomical position in relation to the longitudinal axis of the adjacent second molar. Over the years, different modifications of these scales have been proposed with the aim of improving the prediction of surgical difficulty. In this regard, Pederson proposed a modification of the scale of Pell and Gregory that contemplated an additional factor: the position of the molar.³ Each variable was assigned a score of 1–4 according to its influence upon the difficulty of extraction, and these scores were then summed to yield a final score predicting surgical difficulty: 3–4 (not difficult), 5–7 (moderate difficulty) and 7–10 (great difficulty). This scale has been widely cited in the oral and maxillofacial surgical literature as an easy way to predict the surgical difficulty of impacted mandibular third molar extraction.

Cáceres Madroño et al. added further parameters to the scale of Pedersen, such as mandibular height, distal inclination of the second molar, size and shape of the dental follicle, and development of the roots.⁴ Peñarrocha et al. in turn summed the scores corresponding to pericoronal radiolucency, pericoronal space, Winter's distance and coronal area, and subdivided the size and shape of the roots into two separate parameters: the length of the root and the type of root.⁵ Each variable was scored from 0 to 2, and the individual scores were summed to yield a final surgical difficulty score: 0–5 (not difficult), 6–10 (average difficulty) and over 10 (great difficulty). This is one of the scales involving the largest number of parameters, and higher scores have been shown to correspond to longer osteotomy times and total surgical times—thereby confirming the efficacy of the classification.⁵

Another clinical and radiographic scale for predicting the difficulty of third molar extraction was developed by Romero-Ruiz et al., based on the classical parameters with the addition of integrity of the bone and mucosa covering the third molar.⁶ Minimum surgical difficulty was predicted if the tooth was covered only by mucosa, while maximum difficulty corresponded to molars fully covered by bone and mucosa.

Predicting the surgical difficulty of impacted mandibular third molar extraction is essential for treatment planning and helps assess professional surgical skill, reduces complications, optimizes patient preparation, and minimizes post-operative pain and inflammation.

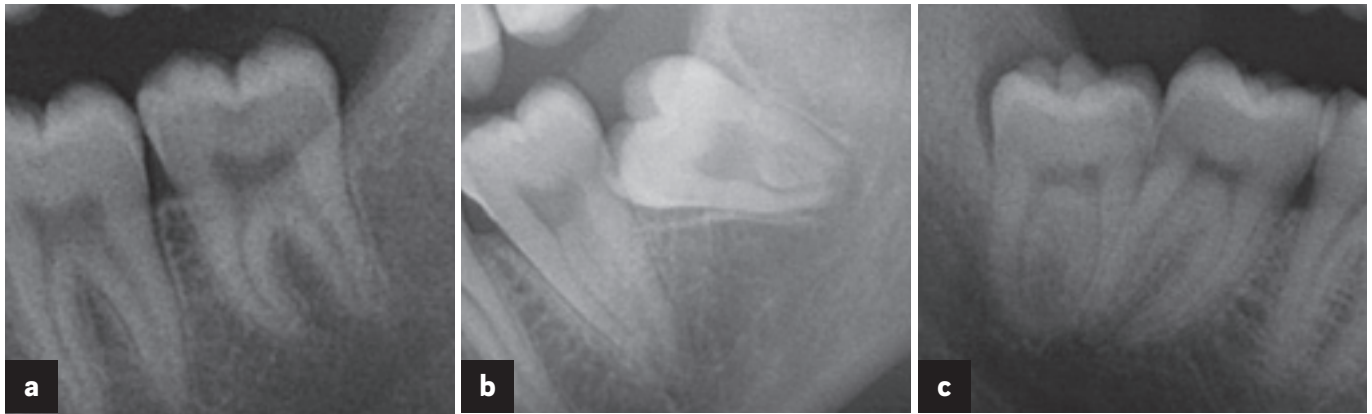
The present study describes a radiographic surgical difficulty scale based on a series of parameters and compares it with osteotomy time, tooth sectioning time, the presence or absence of additional osteotomy, and total surgical time. In addition, actual measurements of the radiographic parameters were taken to identify those that had the greatest impact upon surgical difficulty.

Materials and methods

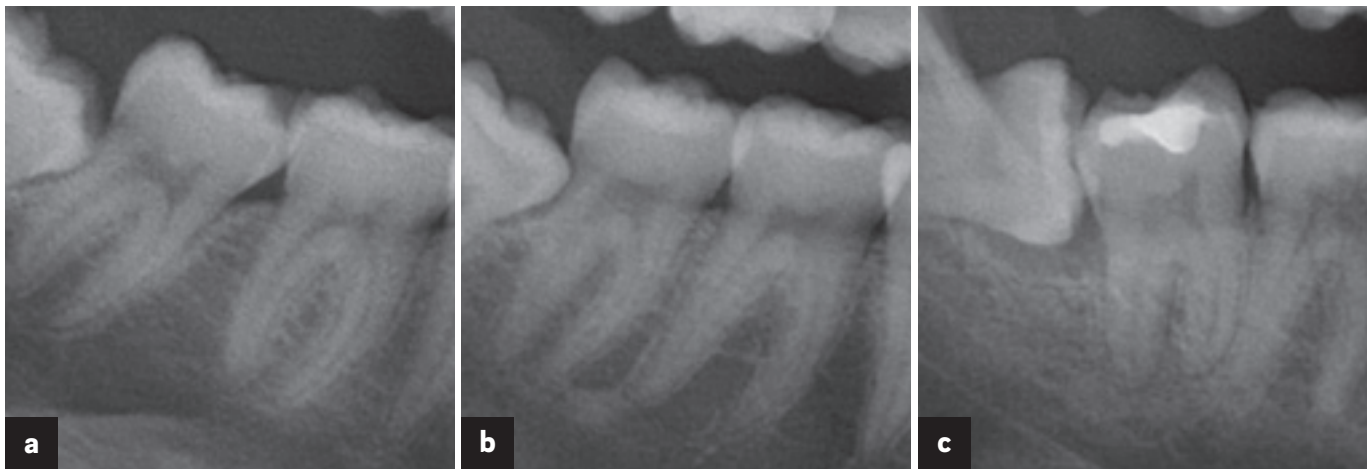
A retrospective study using panoramic radiographs was conducted of patients subjected to surgical extraction of an impacted mandibular third molar in the Department of Stomatology and Maxillofacial Surgery (General University Hospital of Valencia, Valencia, Spain), with recording of the following surgical times: osteotomy time and tooth sectioning time (in seconds) and total surgical time (in minutes), calculated from the start of the incision to the last suture. A presurgical radiographic scale was developed (**Figs. 1–10**), based on ten parameters that were recorded by three dental students of the Faculty of Medicine and Odontology, University of Valencia, Valencia, Spain, using ImageJ software (64-bit; developed by the U.S. National Institutes of Health, Bethesda, Md.)⁷ with calculation of the corresponding mean values: inclination of the third molar, inclination of the second molar, pericoronal radiolucency, root radiolucency, root shape, Winter's distance, distance between the ramus and second molar, width of the third molar, coronal area and root length.

Calibration was carried out based on the calculation of the distortion of the radiographic measurements versus the real measurements of the third molar, using radiographic measurements of the diameter and length of 15 impacted mandibular third molars, exported to ImageJ, and caliper measurements obtained after extraction of the third molar, respectively. The statistical analysis of these dual measurements (ImageJ and calipers) showed the distortion coefficient to be 0.11.

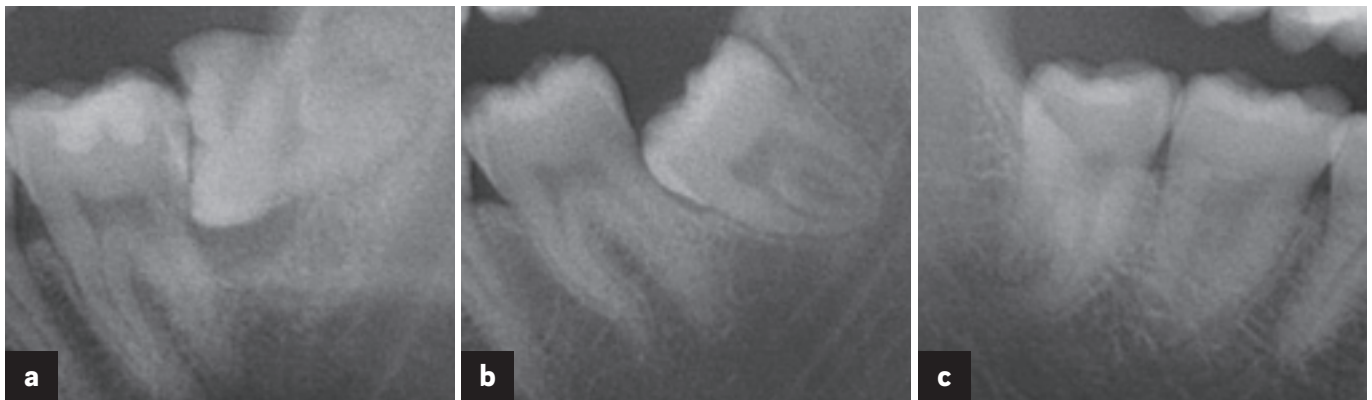
The final score was obtained by summing the individual scores for each parameter, coded



Figs. 1a–c



Figs. 2a–c



Figs. 3a–c

Figs. 1a–c

Inclination of third molar:

- (a) vertical (1);
- (b) mesial (2); and
- (c) distal or horizontal (3).

Figs. 2a–c

Inclination of second molar:

- (a) mesial (1);
- (b) vertical (2); and
- (c) distal (3).

Figs. 3a–c

Pericoronal radiolucency:

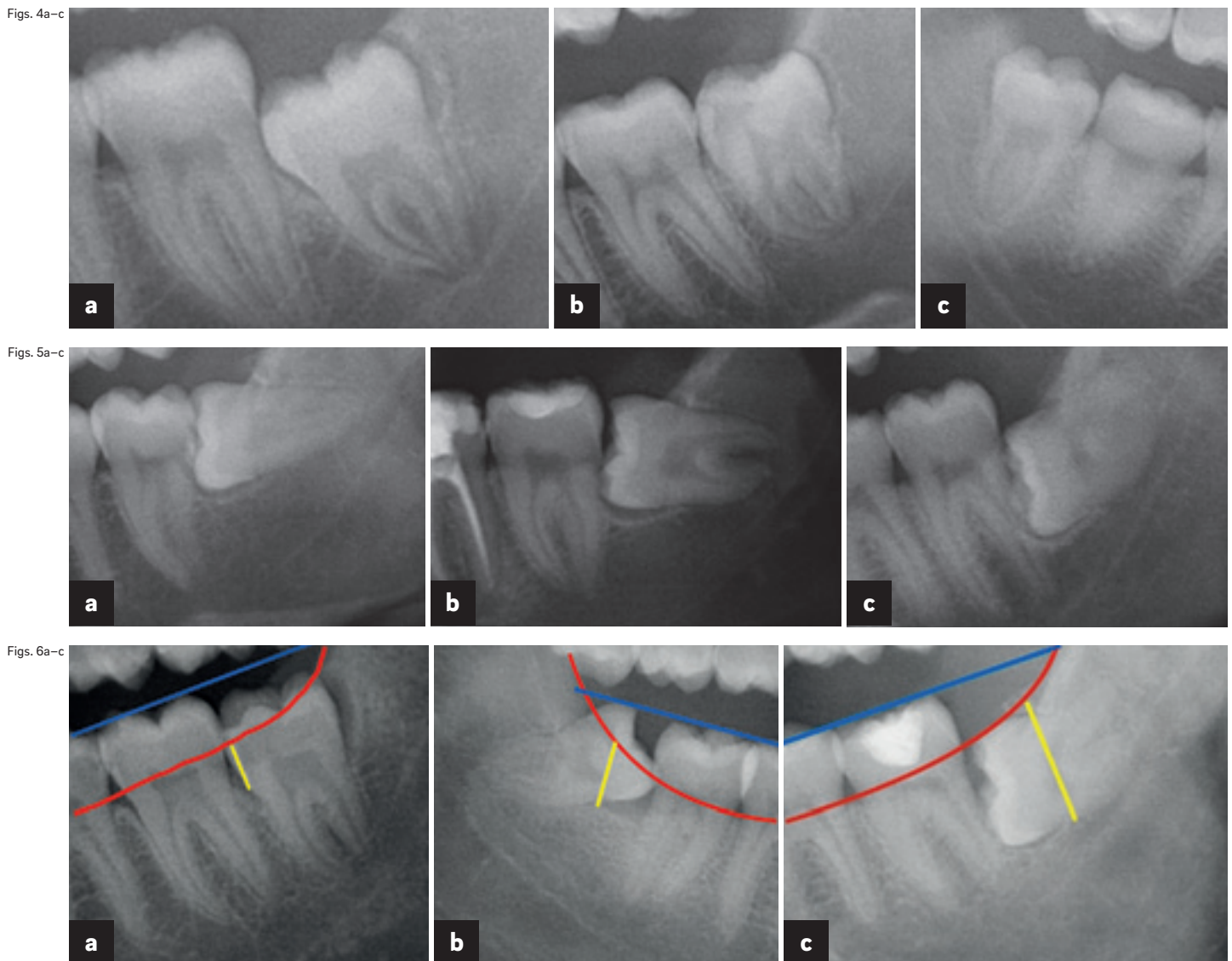
- (a) large (1);
- (b) small (2); and
- (c) not visible (3).

as follows for statistical processing: 1 = not difficult (10–16 points), 2 = average difficulty (17–23 points) and 3 = difficult (24–30 points). The data were processed using the SPSS statistical package (IBM SPSS Statistics for Windows, Version 21.0, IBM, Armonk, N.Y., U.S.). Normal distribution of the variables was evaluated by the Kolmogorov–Smirnov test and was confirmed in all cases. Multivariate analysis was performed, involving the estimation of a general linear multiple regression model for the selected response variable (time) as a function of the study param-

eters and surgical difficulty scores. The accepted level of statistical significance was 5% ($\alpha = 0.05$).

Results

One hundred patients (41 men and 59 women) between 18 and 45 years of age (mean age of 24.9 ± 6.5 years) were analyzed. Mandibular left ($n = 49$) and right ($n = 51$) third molars were extracted. The maximum final score was 27 points, with a minimum final score of 13 (mean final



score of 19.4 ± 2.6 points). Extraction was not difficult in 14.6% of the patients (10–16 points on the surgical difficulty scale), of average difficulty in 79.2% (17–23 points) and difficult in 6.3% (24–30 points).

The maximum ostectomy time was 180 s, with a minimum time of 10 s (mean of 54.4 ± 28.2 s). Tooth sectioning was carried out in 74 cases, with a mean duration of 73.4 ± 45.7 s (maximum of 284 s). The mean total surgical time was 10.8 ± 5.3 min (maximum of 30 min and minimum of 4 min).

The mean total surgical time was significantly longer in the case of molars with mesial inclination and in distal or horizontal presentations ($p = 0.043$). There were no great differences on comparing inclination of the second molar and pericoronal and root radiolucency. However, very significant differences were observed on com-

paring root shape with ostectomy time ($p = 0.001$) and total surgical time ($p = 0.001$; **Table 1**).

The general linear multiple regression model showed the quantitative parameters with the greatest influence upon ostectomy time to be Winter's distance and the distance from the ascending ramus to the second molar. A greater Winter's distance prolonged ostectomy time and, conversely, a greater distance from the mandibular ramus to the distal surface of the second molar was observed to shorten ostectomy time. The parameters found to be linearly correlated to total surgical time were coronal width and the distance from the ramus to the second molar. Total surgical time was longer in the presence of greater coronal width and a shorter distance from the ramus to the second molar. The only variable correlated to tooth sectioning time was coronal width (**Table 2**).

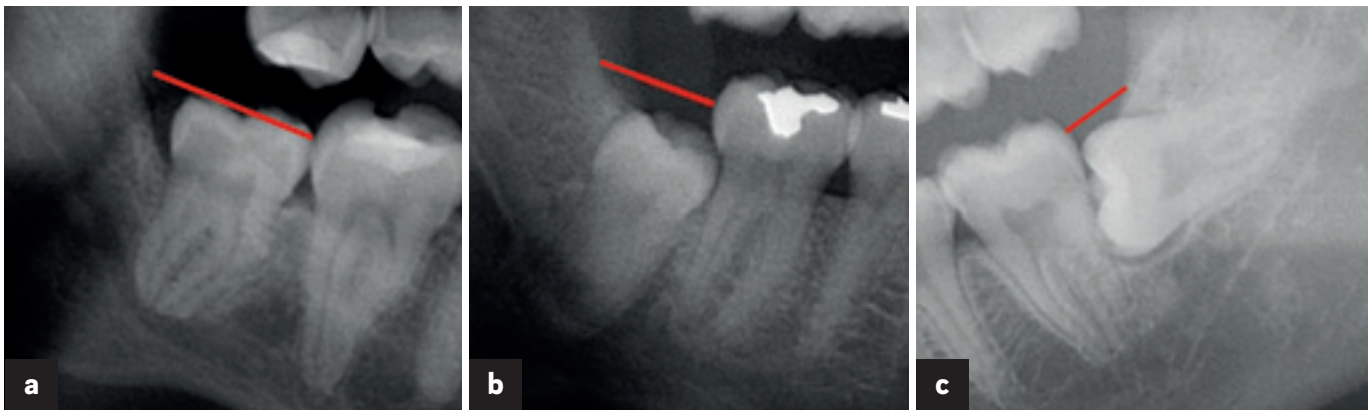
Figs. 4a–c
Root radiolucency:
(a) large (1);
(b) small (2); and
(c) not visible (3).

Figs. 5a–c
Root shape:
(a) single or fused (1);
(b) separate (2); and
(c) dysmorphic or
anomalous (3).

Figs. 6a–c
Winter's distance:
(a) < 5 mm (1);
(b) 5–9 mm (2); and
(c) > 9 mm (3).



Figs. 7a–c



Figs. 8a–c

Figs. 7a–c

Coronal width:
(a) < 10.0 mm (1);
(b) 10.0–11.5 mm (2); and
(c) > 11.5 mm (3).

Fig. 8a–c

Distance from mandibular
ramus to distal surface of the
second molar:
(a) 10.5–14 mm (1);
(b) 8.0–10.5 mm (2); and
(c) 2.0–8.0 mm (3).

According to the model, higher scores on the radiographic scale were associated with longer osteotomy time and total surgical time. For each additional point increase on the scale, the osteotomy time was seen to increase by 2.89 s, while the total surgical time increased by 0.56 s.

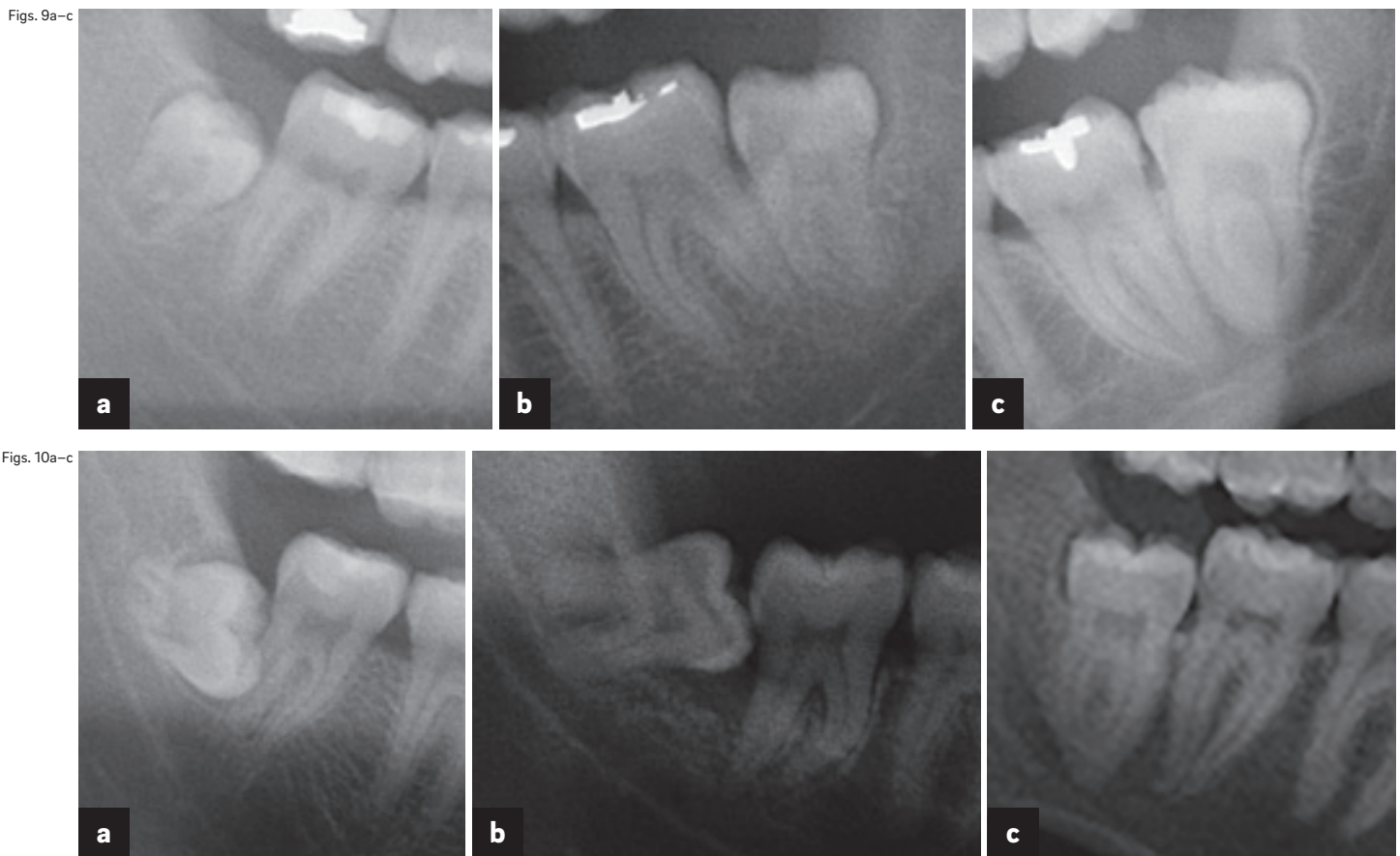
Discussion

In order to successfully predict the difficulty of impacted mandibular third molar extraction, consideration is required of the clinical and radiographic findings, which not only help to plan surgery, but also to increase patient satisfaction with the treatment received. Barreiro-Torres et al. underscored the importance of operator expertise in establishing a prior diagnosis of surgical difficulty, since an expert dental professional tends to underestimate surgery and only examine the radiographs—and this in turn can lead to a failed estimation of extraction difficulty.⁸

The various systems developed for estimating surgical difficulty in extracting impacted mandibular third molars are based on preoper-

ative examination of the panoramic radiographs. Although the classifications of Pell and Gregory¹ and Winter² have served as references, some authors, such as García-García et al.,⁹ have found the classification of Pell and Gregory to offer low sensitivity: It failed to detect many of those cases that subsequently proved to be very difficult when classified with the scale of Parant.¹⁰ This scale,¹⁰ in contrast to the presurgical radiographic scale used in the present study, was designed to assess the difficulty of extraction from the clinical perspective: It is based on the need for rating from greater to lesser surgical effort, but lacks predictive value. Pedersen³ added a further factor to the classification of Pell and Gregory¹—the position of the third molar—and predicted surgical difficulty from the sum of the individual scores of the scale.

With the aim of establishing a preoperative diagnosis of surgical difficulty, various investigators have proposed scales based on a series of clinical and radiographic parameters. Peñarocha et al. added the variables of inclination of the third molar and inclination of the second molar, pericoronal radiolucency, pericoronal space, Winter's distance, length and type of root,

**Figs. 9a–c**

Coronal area:

- (a) 20–75 mm² (1);
 (b) 75–90 mm² (2); and
 (c) 90–130 mm² (3).

Figs. 10a–c

Root length:

- (a) 3.0–8.0 mm (1);
 (b) 8.0–9.5 mm (2); and
 (c) 9.5–13.0 mm (3).

and coronal area to the classical variables of Pell and Gregory,¹ producing the predictive scale with the largest number of variables to date, and adding ostectomy time as an indicator of surgical difficulty.⁵ These authors recorded longer ostectomy times in those cases predicted to be the most difficult extractions according to their classification.⁵ This is consistent with the findings of the present study, in which the variables mesiodistal diameter of the third molar and root radiolucency were added to the classification of Peñarrocha et al.,⁵ and ostectomy time, tooth sectioning time and total surgical time were also considered.

The relationship between the difficulty of extraction and the parameters evaluated by the various presurgical scales is usually appraised on the basis of the total surgical time. The results obtained in the present study point to a linear relationship between the surgical difficulty score and the total surgical time and ostectomy time. Santamaría and Arteagoitia demonstrated a relationship between the difficulty of extraction and the depth of impaction, the width of the periodontal ligament, the inclination of the third molar, its relation to the second molar, and the

distance between the mandibular ramus and the second molar.¹¹ According to Yuasa et al., the most important variables for assessing the difficulty of mandibular third molar extraction are depth level C, Class 3 and large roots, or the combination of these three factors—all of which can be recorded from the panoramic radiographs.¹² López Arranz underscored the importance of evaluating the adjacent teeth: The presence of the first and second molars, their anatomical integrity and separate roots constitute important support for extraction of the third molar.¹³

In the present study, the mesiodistal diameter of the third molar and the distance between the mandibular ramus and the second molar were the parameters most closely correlated to total surgical time. This was in contrast to Carvalho and do Egito Vasconcelos, who identified the number of roots and their morphology, the position of the tooth, the periodontal space, and the relation to the second molar as the only significant predictors.¹⁴ These authors associated the greatest surgical difficulty with Class 3 cases on the scale of Pell and Gregory.¹ The observations of Yuasa et al.¹² and those of the present study indicate that long distances

Variable	Group	Mean ostectomy time by group (seconds)		Mean total surgical time (minutes)	
Inclination of third molar	Vertical (1)	47.7	$p = 0.141$	8.7	$p = 0.043^*$
	Mesial (2)	51.1		10.2	
	Distal or horizontal (3)	63.3		12.9	
Inclination of second molar	Mesial (1)	54.1	$p = 0.996$	10.9	$p = 0.886$
	Vertical (2)	54.5		10.7	
	Distal (3)	53.5		9.0	
Pericoronal radiolucency	Large (1)	48.1	$p = 0.295$	10.6	$p = 0.993$
	Small (2)	58.0		10.7	
	Not visible (3)	51.7		10.9	
Root radiolucency	Large (1)	52.9	$p = 0.939$	10.1	$p = 0.732$
	Small (2)	54.4		11.0	
	Not visible (3)	56.0		10.9	
Root shape	Single or fused (1)	39.4	$p = 0.001^*$	8.1	$p = 0.001^*$
	Separate (2)	47.9		9.5	
	Dysmorphic or anomalous (3)	67.6		13.1	

* $p < 0.05$; ** $p < 0.01$

	Ostectomy time	Tooth sectioning time	Total surgical time
	p -value (r)	p -value (r)	p -value (r)
Winter's distance	0.025* ($r = 0.232$)	0.928 ($r = -0.011$)	0.406 ($r = 0.087$)
Coronal width	0.687 ($r = -0.042$)	0.006** ($r = 0.317$)	0.007** ($r = 0.276$)
Distance from mandibular ramus to distal surface of second molar	0.009* ($r = -0.270$)	0.144 ($r = -0.172$)	0.027* ($r = -0.230$)
Coronal area	0.143 ($r = -0.154$)	0.358 ($r = 0.109$)	0.838 ($r = -0.022$)
Root length	0.470 ($r = -0.077$)	0.324 ($r = 0.118$)	0.157 ($r = 0.150$)

* $p < 0.05$; ** $p < 0.01$ **Table 1**

Study parameters with the greatest influence upon surgical difficulty.

Table 2

Correlation of the quantitative parameters to the variable time according to the general linear multiple regression model.

between the ascending mandibular ramus and the distal surface of the second molar (Class 3) shorten the surgical time.

Conclusion

In summary, an analysis of the surgical difficulty of impacted mandibular third molar extraction is essential for treatment planning and helps assess professional surgical skill, reduces complications, optimizes patient preparation, and minimizes postoperative pain and inflammation.

Our scale is effective, since the mandibular third molars with the highest scores were significantly correlated to longer ostectomy time and

total surgical time. The strongest predictors of ostectomy time were Winter's distance, the distance from the mandibular ramus to the second molar, and root shape, while the strongest predictor of tooth sectioning time was coronal width. The parameters that influenced total surgical time the most were coronal width, mesial and distal or horizontal inclination of the third molar, separate and dysmorphic or anomalous roots, and the distance between the mandibular ramus and the second molar.

Competing interests

The authors declare that they have no competing interests.

References

- Pell G. Gregory B. Impacted mandibular third molars: classification and modified techniques for removal.
→ Dent Dig. 1993;39:330–8.
- Winter GB. Principles of exodontia as applied to the impacted third molar.
→ St Louis: American Medical Book Co; 1926. p.21-58.
- Pederson GW. Oral surgery. Philadelphia: WB Saunders, 1988 (Cited in: Koerner KR. The removal of impacted third molars-principles and procedures.
→ Dent Clin North Am. 1994;38:255-78).
- Cáceres Madroño E, Martínez-González JM, Meniz García C, López Carriches C, Madrigal Martínez-Pereda C. Estudio del grado de dificultad en la extracción de los terceros molares inferiores en relación con la experiencia profesional; Periodo preoperatorio (Parte I).
→ Arch Odontoestomatol. 1998;14(4):229–37.
- Peñarocha M, Sanchis JM, Sáez U, Gay Escoda C, Bagán JV. Escala numérica de valoración de la dificultad quirúrgica en la extracción de 190 terceros molares mandibulares incluidos.
→ Arch Odontoestomatol. 2000;16(2):96–100.
- Romero Ruiz MM. El tercer molar incluido.
→ In: Romero Ruiz MM, Gutiérrez Pérez JL, editors. El tercer molar incluido. Madrid: GSK; 2001. p. 43–69.
- Schneider, C. A.; Rasband, W. S. & Eliceiri, K. W. (2012), "", *Nature methods* 9(7): 671-675
- Barreiro-Torres J, Diniz-Freitas M, Lago-Méndez L, Gude-Sampedro F, Gándara-Rey JM, García-García A. Evaluation of the surgical difficulty in lower third molar extraction.
→ Med Oral Patol Oral Cir Bucal. 2010 Nov 1;15(6):e869–74.
- García-García A, Gude-Sampedro J, Gándara-Rey JM, Gándara-Vila P, Somoza-Martin M. Pell-Gregory classification is unreliable as a predictor of difficulty in extracting impacted lower third molars.
→ Br J Oral Maxillofac Surg. 2000 Dec;38(6):585–7.
- Parant M. Petite Chirurgie de la Bouche. Paris: Expansion Cientifique, 1974. (Cited in: García GA, Sampedro GF, Rey GJ, Torreira GM. Trismus and pain after removal of impacted lower third molars.)
→ J Oral Maxillofac Surg. 1997;55:1223–6.
- Santamaría J, Arteagoitia I. Radiologic variables of clinical significance in the extraction of impacted mandibular third molars.
→ Oral Surg Oral Med Oral Pathol Radiol Endod. 1997 Nov;84(5):469–73.
- Yuasa H, Kawai T, Sugiura M. Classification of surgical difficulty in extracting impacted third molars.
→ Br J Oral Maxillofac Surg. 2002 Feb;40(1):26–31.
- López Arranz JS. Diagnóstico por la imagen.
→ In: López Arranz JS, editor. Cirugía oral. Madrid: Interamericana-McGraw-Hill. 1991. p. 65–118.
- Carvalho RW, do Egito Vasconcelos BC. Assessment of factors associated with surgical difficulty during removal of impacted lower third molars.
→ J Oral Maxillofac Surg. 2011 Nov;69(11):2714–21.

Kinesiographic analysis of lateral excursive movement on the horizontal plane: the retrusive component

Andrea Papini,^a Gianfranco Cesaretti^b
& Patrizia De Fabianis^c

^a Private practice in Prato, Italy

^b ARDEC Academy, Rimini, Italy

^c Turin University, Turin, Italy

Corresponding author:

Dr. Gianfranco Cesaretti

Via Maria Montessori 9
60022 Castelfidardo AN
Italy

T +39 071 782 2800
giancesa55@gmail.com

How to cite this article:

Papini A, Cesaretti G, De Fabianis P. Kinesiographic analysis of lateral excursive movement on the horizontal plane: the retrusive component. *J Oral Science Rehabilitation*. 2017 Mar;3(1):60–7.

Abstract

Objective

The temporomandibular joint (TMJ) has a functionally complex articulation that during phylogeny underwent an adaptation also linked to posture change after the acquisition of upright posture and subsequent reduction of the postglenoid process. This articulation supports numerous functions of the stomatognathic apparatus, and the part physiologically designed to withstand greater loads associated with mastication is essentially the frontal one; the rear portion of the TMJ is unfit to absorb retrusive forces owing to the poor support of the thin bone component and the histological characteristics of the tissue component. The purpose of this article was to analyze the angles of lateral tracings both on the frontal plane and on the horizontal one through kinesiographic analysis (functional masticatory angle of Planas and functional horizontal masticatory angle) in seeking to observe their mutual relations with respect to those planes.

Materials and methods

The study was performed on 115 patients who presented with asymmetrical laterality movements. The sample was made up of 32 males and 85 females aged between 17 and 84.

Results

Ninety-eight (85%) of the lateral tracings examined showed a consistency between the inclination of the tracings on the frontal and horizontal planes. Seventeen (15%) showed an inconsistency between the inclination of the tracings on the horizontal and frontal planes.

Conclusion

The study found a correspondence on the working side between a steep laterality on the frontal plane and a posterior trajectory on the horizontal plane. The reduction of the steepness of the functional masticatory angle of Planas tends to reduce the posteriorization of the functional horizontal masticatory angle, promoting the recovery of alternating unilateral masticatory function.

Keywords

Temporomandibular joint (TMJ), Gothic arch, functional masticatory angle of Planas (AFMP), functional horizontal masticatory angle (AFMO), masticatory cycle, lateral retrusion Posselt volume.

Introduction

The phylogenetic evolution has produced a number of postural changes related to the attainment of the upright position, and the TMJ, in its relationship to the tympanic cavity, has undergone a transformation. In fact, while both in anthropomorphic and in nonanthropomorphic monkeys, the rear portion of the TMJ is bounded posteriorly by the postglenoid process¹—a bony protuberance of marked thickness that delimits and separates the mandibular fossa from the tympanic cavity²—in *Homo sapiens*, this process has had a progressive thinning, ending in a factual disappearance. Therefore, in modern man, the rear wall of the mandibular fossa forms the front wall of the tympanic cavity. It is a thin layer, crossed by a canal (named Huguier's or Civinini's canal, after the researcher who first described it) that connects the two structures.^{3,4} The soft-tissue that makes up the retrodiscal portion of the TMJ is histologically unfit to withstand compressive forces, as the retrodiscal portion of the TMJ, richly vascularized and innervated,⁵ essentially acts as a hydrodynamic support. It is worth considering that some of the connective fibers of the retrodiscal tissue penetrate the Huguier's canal,⁶ forming the discomalleolar ligament and reaching the tympanic cavity, attaching to the malleus head and neck. In summary, these characteristics make the posterior region of the TMJ unsuitable for bearing the functional loads of mastication and swallowing, since, under optimum conditions, the condyle should never cause excessive compression of retrodiscal tissue. In fact, prolonged and constant compressive stress, linked for instance to dysfunctional situations, determines stresses that tend over time to result in reparative fibrotic processes,^{7,8} leading to structural changes^{9,10} responsible for a different biomechanical response of the tissue.

The study of mandibular movement on the horizontal plane is associated with the interincisal point movement. Gysi in his records¹¹ was the first to describe the Gothic arch: In classic gnathology the lateral tracings on the horizontal plane are described as an anterolateral shift. Symmetrical on both sides, the lateral tracings on the frontal plane are usually described as an anterolateral development. In patients with dysfunction, kinesiographs show as a norm a deformation of the Gothic arch: One of the two lateral tracings tends to lose the anterolateral direction to acquire a tendency to posteriorization (**Fig. 1**). Guichet has described a 60° conic

volume in which the working condyle can shift during the lateral excursion.¹² The interincisal point used in the recording of the Gothic arch can be placed geometrically in relation to the condyles.^{13,14} Mongini has described in the position of maximum intercuspation the relationships between the interincisal point and the position of the condyles.¹⁵

Through the aid of a kinesiograph during lateral excursion, the tracing of the interincisal point on the horizontal plane can be placed in relation to the movement of the working condyle: during lateral excursion, the balancing condyle always shifts in the anteromedial direction, while the working condyle can move both in the anterolateral direction and in the posterolateral one. The interincisal point will have the same tendency of the working condyle movement (**Fig. 2**). The Gothic arch, which highlights the excursive interincisal movements of the point on the horizontal plane, can be considered a horizontal section of a volume defined by Posselt with the trajectories of maximum movements of opening, laterality and protrusion.¹⁶ The volume of Posselt can be defined as a 3-D perimeter within which the jaw can achieve its functional movements.

In patients with dysfunction, an asymmetrical Gothic arch, altered and reduced in its developments, is practically the norm and must be interpreted as a planar representation of the deformation of the entire Posselt volume (**Fig. 3**). Alternating unilateral mastication allows better control of the food bolus and of the forces that develop during mastication; from a biomechanical point of view, it tends to symmetrically allocate the distribution of load on the dental, periodontal, bone, joint and muscle structures. This alternation of the masticatory cycles is permitted by the symmetry of the functional masticatory angles of Planas (AFMP, angles fonctionnels masticatoires de Planas). The AFMPs are the angles that are created on the frontal plane between the lateral distances and the horizontal plane, while the functional horizontal masticatory angles (AFMO) are those that are created on the horizontal plane between the lateral distances and the frontal plane (**Fig. 4**). In the presence of a retrusive AFMO, there will be a deformation of the Gothic arch structure (**Fig. 1**).

The purpose of this work was to analyze the angles of lateral tracings, seeking to observe the relation of coherence between the frontal plane and the horizontal plane (AFMP/AFMO). This consistency respects the correspondence

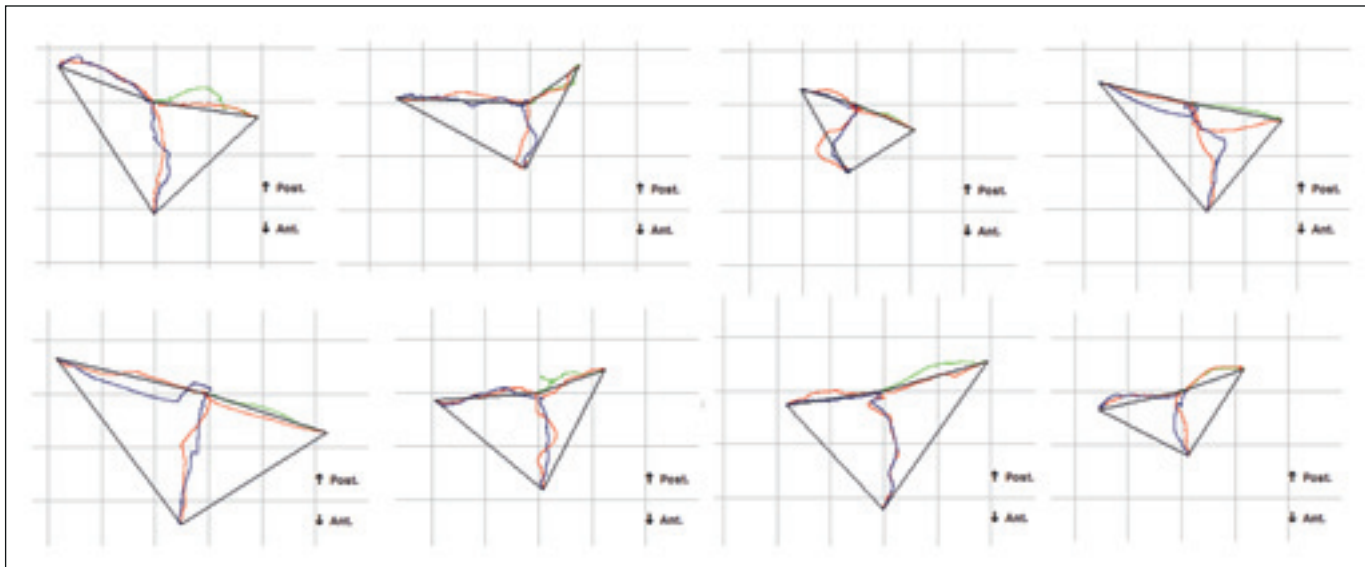


Fig. 1

Fig. 1
Kinesiographic tracings:
dysfunctional Gothic arches.

Fig. 2
Relation between the
interincisal point movement
and the working condyle
movement.

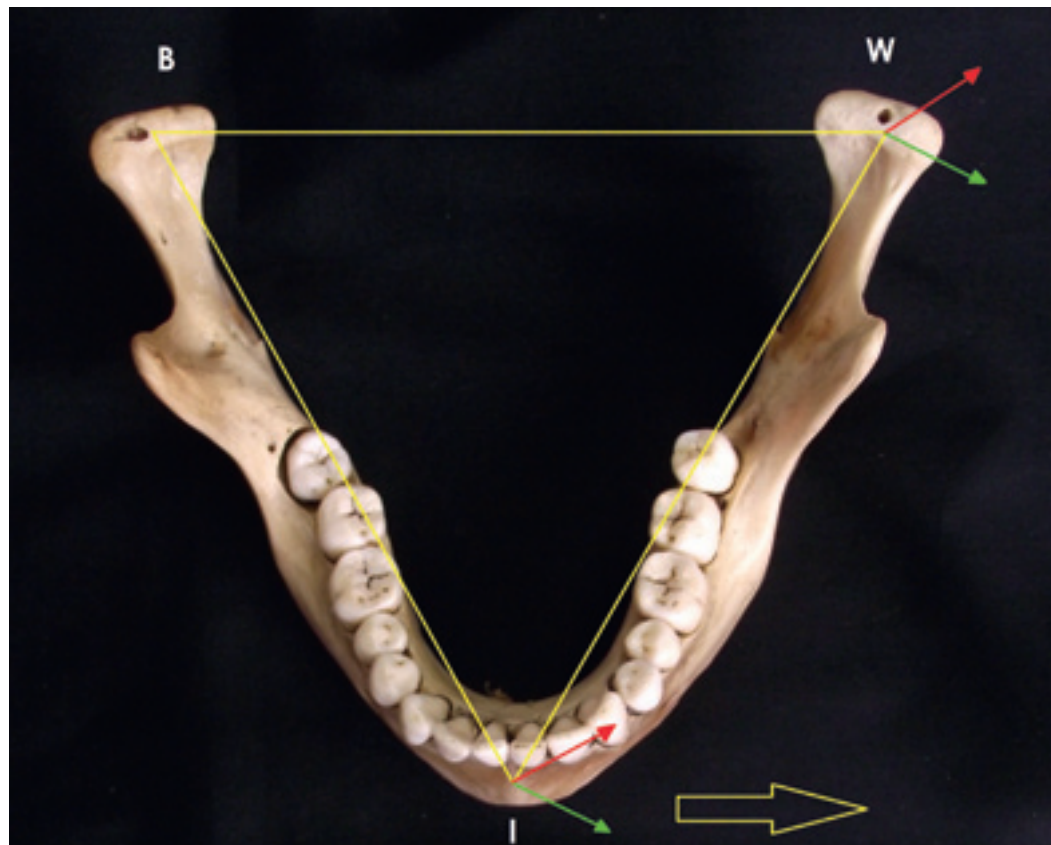


Fig. 2

Fig. 3

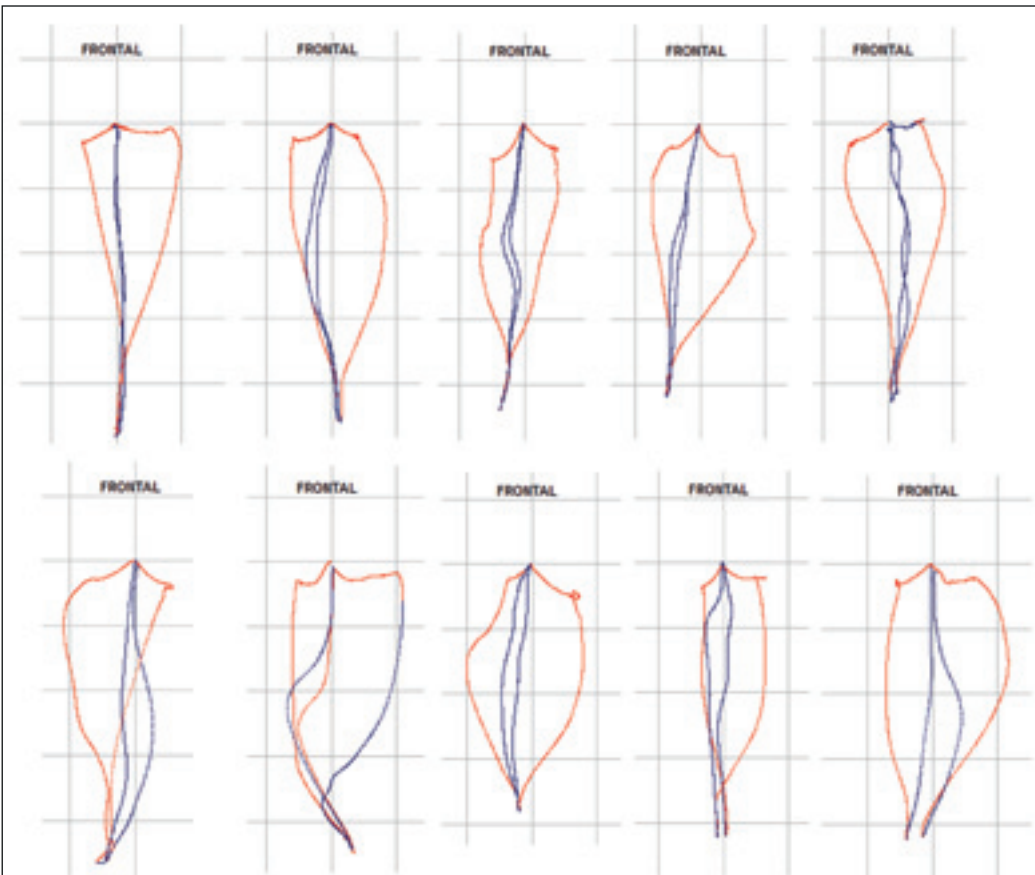


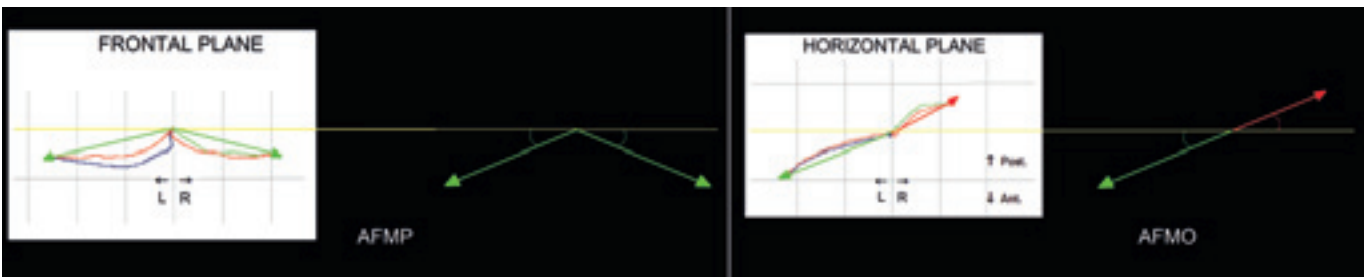
Fig. 3

Posselt diagrams in patients with dysfunction.

Fig. 4

Frontal plane: AFMP.
Horizontal plane: AFMO.

Fig. 4



between the front slope of the AFMP and anteroposteriority of the AFMO.

plane, and the magnet was placed in an equidistant position with respect to the two detectors of the kinesiograph.

Materials and methods

The study was performed on 115 patients who presented with asymmetrical lateral excursion. The sample was made up of 32 males and 85 females aged between 17 and 84. The instrument used for this study was a Bioket kinesiograph (Bioket, S.Benedetto del Tronto, Italy). Eligible subjects were placed in a sitting position, not on the dental chair, feet with full plantar support on the floor. The kinesiographic mask was positioned with reference to the horizontal

Results

Ninety-eight (85%) of the lateral tracings examined with respect to the frontal plane showed consistent results, demonstrating the correspondence between the greater steepness of the AFMP and the posteriorization of the AFMO. The steepest laterality in the frontal plane was found to be the most posterior on the horizontal plane. The remaining 17 (15%) tracings failed to show this kind of correspondence

Fig. 5

Correspondence between a steep AFMP and a retrusive AFMO (always found to be < 1).

Fig. 6

Asymmetric lateral excursion.

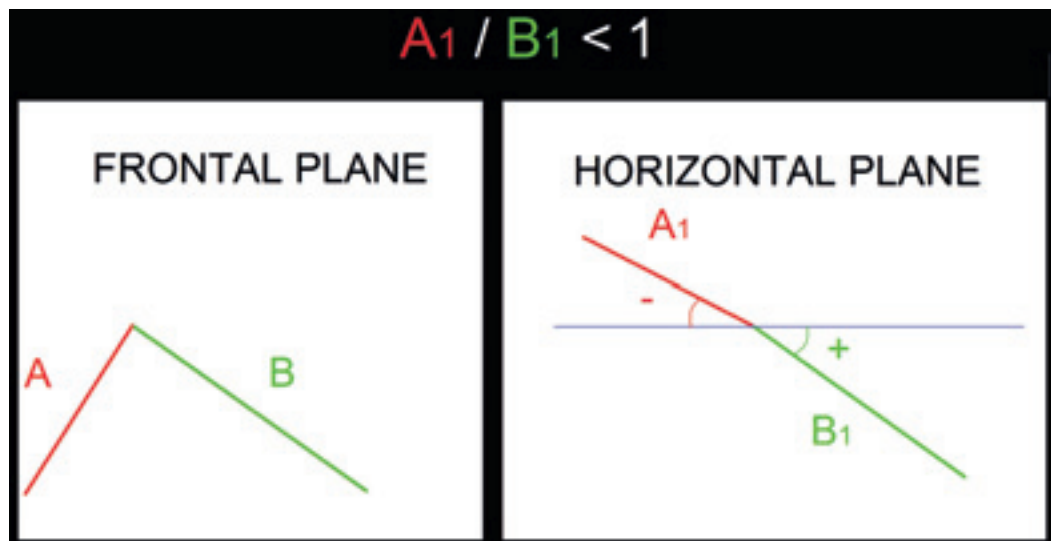


Fig. 5

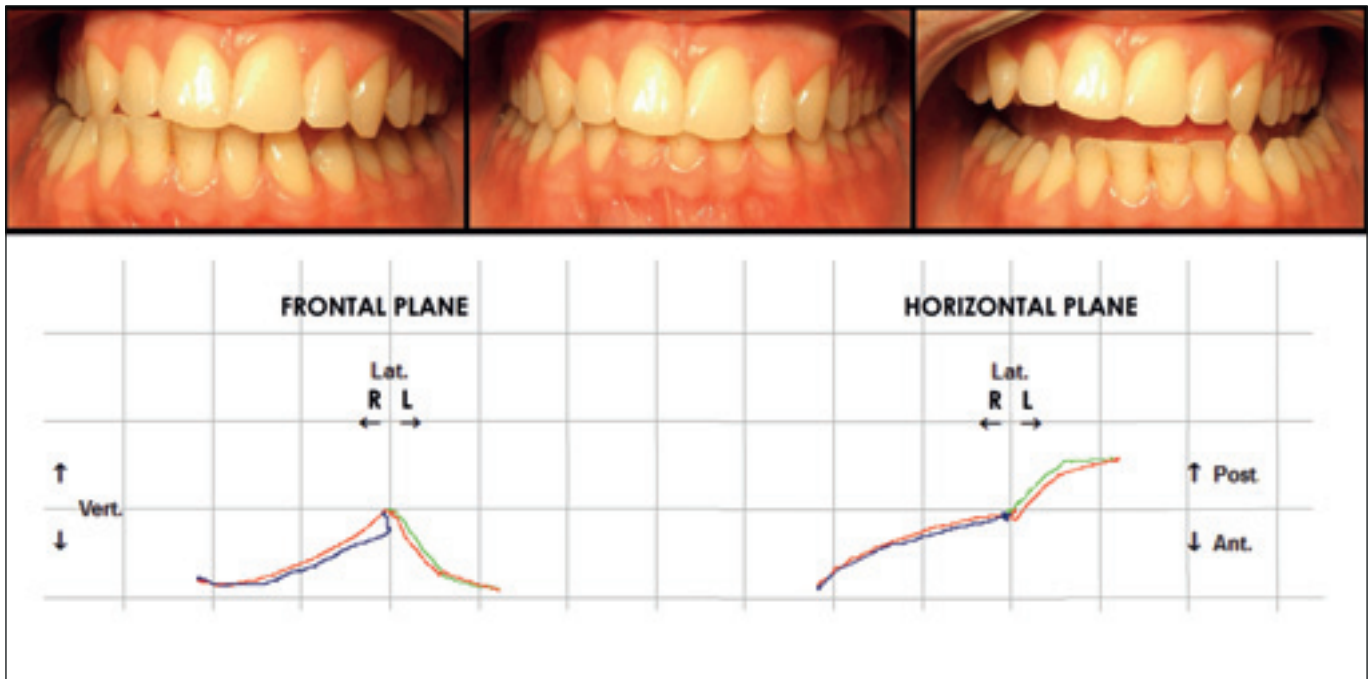
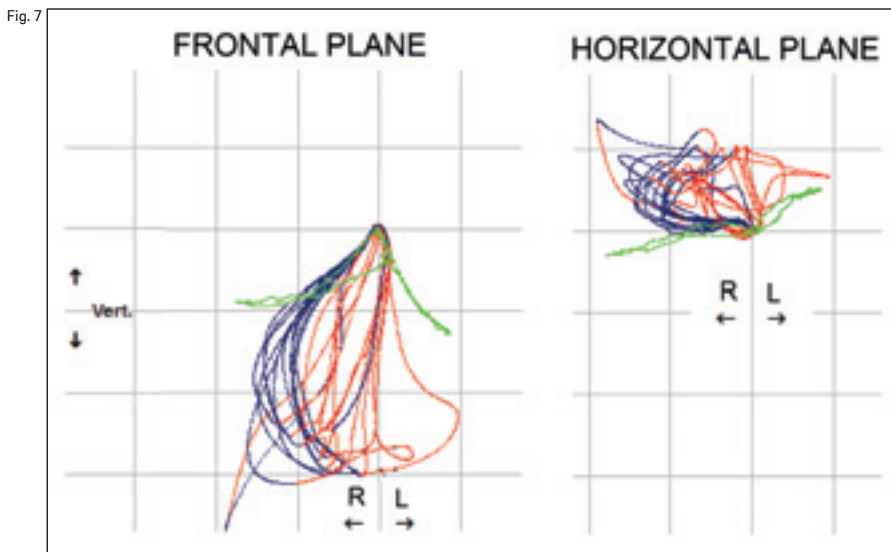


Fig. 6

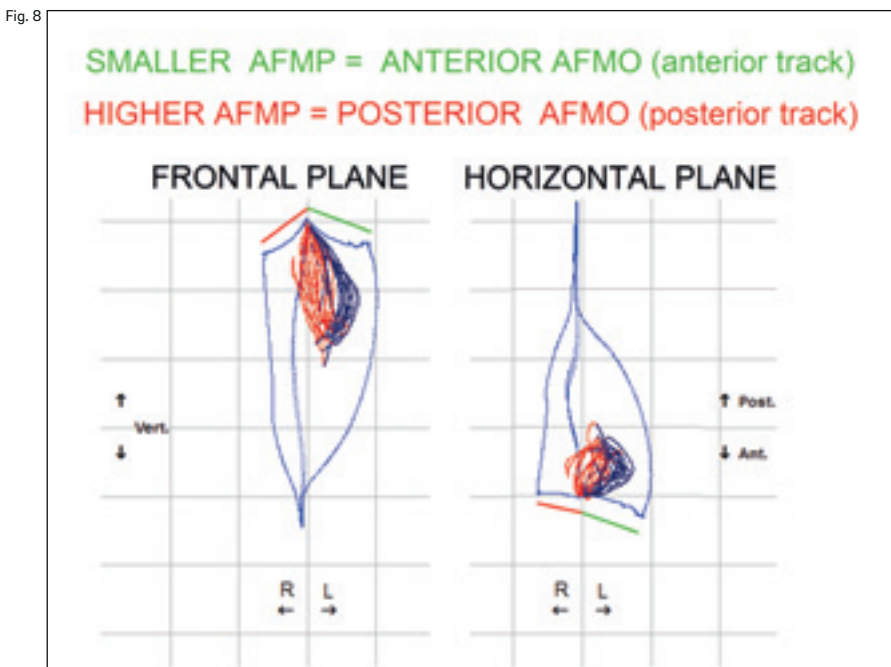
between the AFMP and the AFMO. On the horizontal plane, the lateral retrusion formed an angle with the frontal plane that was given a negative value, and the angles formed by latero-protrusive tracings were given a positive value. On the horizontal plane in all of the 98 coherent paths, the relationship between the angle of the tracing corresponding to that steeper on the frontal plane and that corresponding to the less steep was always found to be < 1 , showing the correspondence between a steep AFMP and a retrusive AFMO (**Fig. 5**). The average confirmed precisely the correspondence between a steep AFMP and a retrusive AFMO: $A1/B1 = -0.589432199$.

Discussion and conclusion

Planas in defining the AFMP emphasized the pattern of unilateral mastication.¹⁷ Predominantly unilateral mastication usually occurs when there is a side of the mouth in which the function can be performed with more ease and efficiency compared with the contralateral side (**Fig. 6**). Predominantly unilateral mastication tends to develop from the side with less steep laterality or with a smaller AFMP. The study of laterality with a Bioket kinesiograph has permitted to highlight also on the horizontal plane the asymmetry defined by Planas on the frontal plane: On the horizontal plane, the side with the less

**Fig. 7**

Frontal plane: masticatory cycles in predominantly unilateral mastication on the side with the less steep AFMP. Horizontal plane: masticatory cycles in predominantly unilateral mastication on the side with the advanced AFMO.

**Fig. 8**

Unilateral masticatory cycles.

steep AFMP (usually the one with an easy lateral excursion and functionally prevailing masticatory side) tends to correspond to the side with the tracing that is expressed in anteriority (**Fig. 7**) and vice versa. This is referred to as the consistency of the tracings of laterality between the front and the horizontal planes.

An AFMO tending to posteriorization is an index of laterality with a retrusive component: The entry stage of the masticatory cycle (during which the masticatory forces reach their maximum intensity) tends to take place with an unfavorable condyle–fossa relationship. A lateral retrusion tends to create a compression of the retrodiscal tissue, hindering proper mastication

and encouraging mastication on the contralateral side (**Fig. 8**).

By decreasing the steeper slope and the lateral tracings symmetrizing the AFMP on the frontal plane, the retrusion of the corresponding AFMO tended to reduce, resulting in a regularization of the Gothic arch and of the Posselt volume and favoring the restoration of alternating unilateral mastication (**Fig. 9**). Since the tracing of the Gothic arch is a horizontal section of the Posselt volume, the arch regularization determines a volume regularization that allows the jaw to move freely in mastication (**Fig. 9**).

Therefore, analysis of lateral excursion movements with evaluation of the prevailing

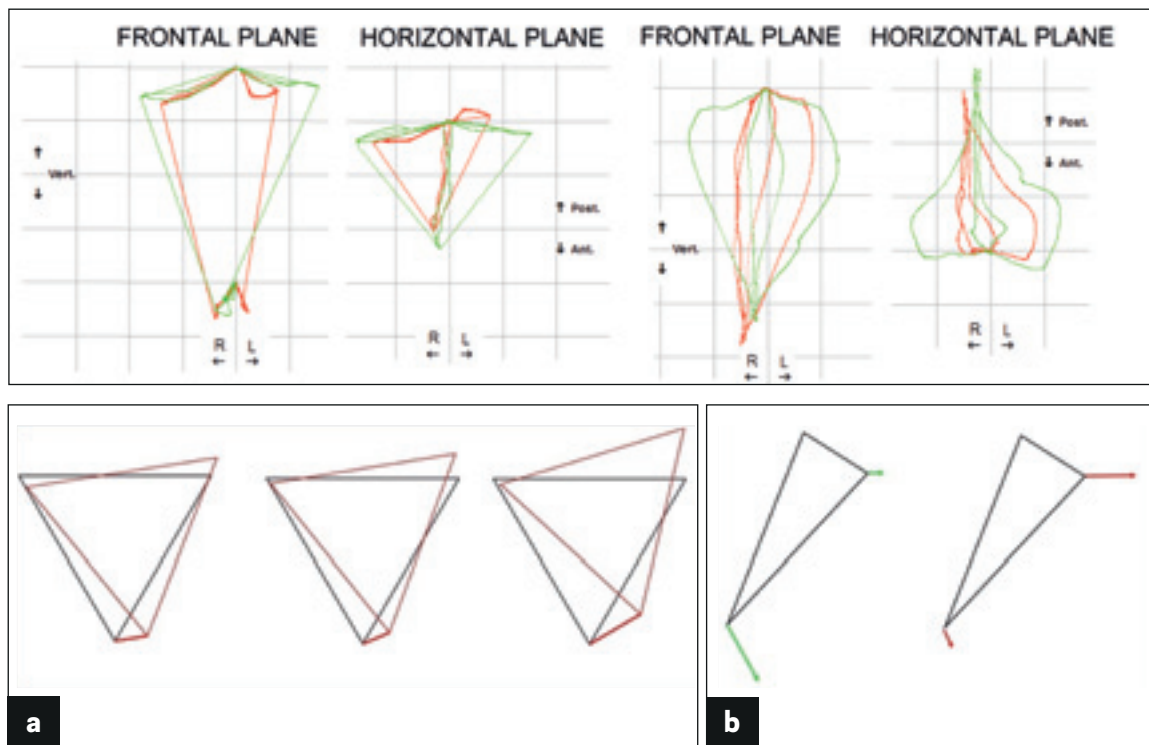


Fig. 9

Figs. 10a & b

Fig. 9

Decreasing the AFMP on the frontal plane tended to reduce the retrusion of the corresponding AFMO on the horizontal plane, correcting and regularizing the Posselt volume.

Figs. 10a & b

Bonwill's triangle.

masticatory side cannot exclude analysis of lateral excursion on the horizontal plane. In kinesiographic tracings of patients with dysfunction, the asymmetries of the AFMP and AFMO (and therefore of the Gothic arch and the Posselt volume) are largely the norm: Steeper laterality on the frontal plane will tend to have a retrusive tracing (absolute or relative to the contralateral side) on the horizontal plane.

The back thrust of the working condyle in lateral retrusive tracings of will tend to be

- directly proportional to the posteriorization of the interincisal tracing;
- directly proportional to the length of the tracing—the more the lateral tracing has to express its posterior movement, the more the working condyle will tend to posteriorization (**Fig. 10a**);
- inversely proportional to the vertical component of the movement: because the lateral excursion is expressed on the different spatial planes, the vertical component is as if it tended to stop the retrusive push of the working condyle (**Fig. 10b**).

A posterior AFMO (absolute or relative to the contralateral side) indicates a difficult, countered laterality and will tend to highlight the side with problematic masticatory function. Reducing the

steeper inclination of the AFMP will tend to reduce the retrusion of the corresponding AFMO, regularizing the Gothic arch and the Posselt volume, and this will promote the restoration of alternating unilateral mastication.

Acting properly on the occlusal surfaces, we are able to influence the whole of the mandibular dynamics by changing not only the movements related to occlusal guides, but also the mandibular movements in full, both in the amount of maximum openness, in their transverse width and in their inclination. Premature contacts or interferences that induce retrusion of the lateral excursion on the horizontal plane with posteriorization of the entry phase of the masticatory cycle will tend to favor prevalent mastication on the contralateral side. With asymmetry correction of lateral excursion, we tend to decrease the condylar retrusion, expand and symmetrize the Gothic arch and the volume of Posselt, thus directing the masticatory function to a physiological alternating unilateral mastication.

Competing interests

The authors declare that they have no conflict of interest regarding the materials used in the present study.

References

1. Lockwood CA, Lynch JM, Kimbel WH. Quantifying temporal bone morphology of great apes and humans: an approach using geometric morphometrics. → J Anat. 2002 Dec;201(6):447–64.
2. Newell L, Wood B. Cranial base evolution within the hominin clade. → J Anat. 2008 Apr;212(4):455–68.
3. Buffoli B, Galli M, Papini A, Ferrari M, Belotti F, Labanca M, Tschabitscher M, Rodella LF. Morphometric analysis of Huguier's canal by cone beam CT. → Italian J Anat Embriology. 2013;118(2 Suppl):36.
4. Şencimen M, Yalçın N, Doğan, Varol A, Okçu KM, Ozan, Aydınтуğ YS. Anatomical and functional aspects of ligaments between the malleus and the temporo-mandibular joint. → Int J Oral Maxillofac Surg. 2008 Oct;37(10):943–7. Epub 2008 Sep 2.
5. Benigno MI, Azeredo RA, Lemos JL, König B Jr, Liberti EA. The structure of the bilaminar zone in the human temporomandibular joint: a light and scanning electron microscopy study in young and elderly subjects. → iJ Oral Rehabil. 2001 Feb;28(2):113–9.
6. Sato A, Asaumi R, Imura K, Kawai T, Yosue T. Classifications of tunnel-like structure of human petrotympanic fissure by cone beam CT. → Surg Radiol Anat. 2008 Jun;30(4):323–6. Epub 2008 Feb 21.
7. Scapino RP. Histopathology associated with malposition of the human temporomandibular joint disc. → Oral Surg Oral Med Oral Pathol. 1983 Apr;55(4):382–97.
8. Mazza D, Stasolla A, Kharrub Z, Maccioni F, Marini M. MRI evaluation of morpho-structural alterations of the retrodiscal tissue in condylo-meniscal incoordination of the TMJ: usefulness of individualised T2-weighted TSE sequences. → Radiol Med. 2004 Mar;107(3):261–8.
9. Westesson PL, Paesani D. MR imaging of the TMJ: decreased signal from the retrodiscal tissue. → Oral Surg Oral Med Oral Pathol. 1993 Nov;76(5):631–5.
10. Hall MB, Brown RW, Baughman RA. Histologic appearance of the bilaminar zone in internal derangement of the temporomandibular joint. → Oral Surg Oral Med Oral Pathol. 1984 Oct;58(4):375–81.
11. Gysi A. Handbuch der Zahnheilkunde. Vol. 3. → Munich: Verlag von J.F. Bergmann; 1930.
12. Molina M. Concetti fondamentali di gnatologia moderna. 2nd ed. → Milan: ILIC; 2002. 513 p.
13. Mongini F. A combined method to determine the therapeutic position for occlusal rehabilitation. → J Prosthet Dent. 1982 Apr;47(4):434–9.
14. Mongini F. Condyle position and occlusal position abnormalities. → In: Solberg WK, editor. Abnormal jaw mechanics: diagnosis and treatment. Chicago: Quintessence; 1984.
15. Mongini F. L'apparato stomatognatico. Funzione, disfunzione e riabilitazione. Ed. Internazionali. → Milan: Scienza e tecnica dentistica; 1989.
16. Posselt U. The physiology of occlusion and rehabilitation. 2nd ed. → 1968.
17. Planas P. Rehabilitación neuro-oclusal (RNO). 2a ed. → Barcelona: Masson-Salvat.

Open-cohort prospective study on early implant failure and physiological marginal remodeling expected using sandblasted and acid-etched bone level implants featuring an 11° Morse taper connection within one year after loading

Abstract

Objective

The objective of this study was to evaluate the implant survival and success rates as well as the physiological marginal bone remodeling expected using Osstem implants.

Materials and methods

This investigation was designed as an open-cohort prospective study on completely or partially edentulous patients who received at least one bone level implant with a sandblasted and acid-etched surface and an 11° Morse taper connection. Outcome measures were the success rates of the implants and prostheses, complications, marginal bone level changes, insertion torque, implant stability quotient, bone density and soft-tissue biotype.

Results

A total of 243 implants were placed in 90 consecutive patients and followed up for a minimum period of one year after loading (mean of 17.6 ± 2.5 months; range of 12–24 months). Five implants failed in five patients, resulting in a cumulative implant survival rate of 97.9%. Insertion torque of < 35 N cm was found to be a risk factor for implant failure ($p = 0.0068$). No definitive prosthesis failed, resulting in a cumulative prosthetic survival rate of 100%. Four patients experienced one technical complication each, resulting in a cumulative prosthetic success rate of 97.2%. The cumulative mean marginal bone loss between implant placement and the follow-up one year after loading was 0.37 ± 0.25 mm (95% CI: 0.26–0.30). Comparison of marginal bone loss and the investigated risk factors found statistically higher marginal bone loss for smokers, a thin gingival biotype and guided bone regeneration ($p < 0.05$).

Conclusion

Low implant failure and physiological marginal bone remodeling of 0.37 mm within one year after loading can be expected using Osstem TSIII implants in the daily practice.

Keywords

Dental implants, bone remodeling, conical connection, survival rate, complications.

Marco Tallarico^a & Silvio Mario Meloni^b

^a Aldent University, Tirana, Albania; private practice, Rome, Italy

^b University of Sassari, Sassari, Italy; private practice, Arzachena, Italy

Corresponding author:

Dr. Marco Tallarico

Via di Val Tellina 116
00151 Rome
Italy

T +39 06 663 0646
me@studiomarcotallarico.it

How to cite this article:

Tallarico M, Meloni SM. Open-cohort prospective study on early implant failure and physiological marginal remodeling expected using sandblasted and acid-etched bone level implants featuring an 11° Morse taper connection within one year after loading. J Oral Science Rehabilitation. 2017 Mar;3(1):68–79.

Introduction

During the first year of function, a certain amount of physiological marginal bone loss is expected around a dental implant, both horizontally and vertically; thereafter, minimal further bone loss has been observed.^{1,2} Marginal bone loss (MBL) of 1.5–2.0 mm during the first year of function has been assumed as normal.² Afterward tissue stability is expected.^{2–4} However, the criteria for defining success in implant dentistry are under constant debate in consensus statements and observational studies. Papaspyridakos et al. proposed parameters related to soft- and hard-tissue stability that can influence the progression of MBL around implants, but is not clear whether the physiological bone remodeling is prosthesis-related, host-related, implant-related or load-dependent.⁴ As a result, although numerous studies have reported improvements in implant design and protocols to minimize this MBL, the utilized criteria for success have remained unchanged.

Several factors may increase MBL around dental implants, including surgical trauma, implant–abutment connection type, biological width establishment, mucosal tissue thickness, keratinized tissue width and bone density.^{5–7} The stress and strain concentrated at the periimplant crestal bone result in structural and morphological changes, especially during the first year after loading.⁷ Hence, the bone remodeling process is one of the critical factors in evaluating implant success.⁸ In addition, iatrogenic factors may contribute to periimplant MBL, such as implant positioning, implant–abutment microgap, lack of passive fit of the superstructure and occlusal overloading.^{9–13}

Many pathological factors, including history of periodontitis, smoking, poor plaque control, genetic predisposition and diabetes, may produce an inflammatory reaction around an implant; nevertheless, no consensus exists with regard to a suitable definition of “periimplantitis” based on clinical and radiographic signs and symptoms or the best way to manage this emerging challenge.^{13,14} The American Academy of Periodontology in 2013 defined “periimplantitis” as an inflammatory reaction associated with the loss of supporting bone beyond the initial biological bone remodeling around an implant in function.¹⁵

The aims of the present study were to report the survival and success rates of dental implants

placed in private practice and representing the daily realities of implant treatment, and then to determine the entity of the physiological marginal bone remodeling expected using Osstem implants. The data were analyzed to determine any statistical relationships between explanatory variables and early implant failure and physiological marginal bone remodeling (within one year after loading). This study is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology statement for improving the quality of observational studies.¹⁶

Materials and methods

This investigation was designed as an open-cohort prospective study. All of the surgical and prosthetic procedures were performed in a private center in Rome, Italy, by an implant-based certified clinician (MT) between September 2014 and December 2016. All of the participants were enrolled and treated in consecutive order after being informed about the clinical procedures, materials to be used, benefits, and potential risks and complications, and once their written consent had been obtained. This study was conducted according to the principles embodied in the Helsinki Declaration of 1975, as revised in 2008.

Any completely or partially edentulous patients who received at least one bone level implant with a sandblasted and acid-etched surface and a Morse taper connection (Osstem TSIII, Osstem, Seoul, South Korea) were considered eligible for this study, independent of the implant and prosthetic protocols used. Exclusion criteria were general medical contraindications to oral surgery (American Society of Anesthesiologists Physical Status Class III or IV), patients treated or under treatment with intravenous aminobisphosphonates, and previous radiotherapy of the oral and maxillofacial region within the last five years. Patients who were diagnosed with active periodontal disease (≥ 6 mm probing depth) underwent periodontal surgery or initial therapy alone, prior to implant surgery.

Surgical and prosthetic protocols

Preoperative photographs, periapical radiographs, panoramic radiographs or cone beam

computed tomography (CBCT) scans, and model casts were produced for all of the patients, for initial screening and case evaluation. Before implant placement, all of the patients received a single dose of an antibiotic (2 g of amoxicillin or 600 mg of clindamycin if allergic to penicillin). Prior to the start of surgery, the patients rinsed with 0.2% chlorhexidine for 1 min. The patients received Osstem TSIII bone level implants with a rough surface (R_a of 2.5–3.0 μm) sandblasted with alumina and acid-etched and featuring an internal hex and 11° conical connection. Implant placement was performed using either computer-guided template-assisted implant placement or conventional freehand surgery. Most of the implants were placed according to the drilling protocol recommended by the manufacturer. In the case of immediate loading, post-extractive implants and poor bone quality, the drilling protocol was customized (**Table 1**).

Surgical protocols included placement in completely or partially edentulous healed ridges with or without bone grafting, as well as in fresh extraction sockets using a flapless or a flap approach. A flapless approach was planned in the case of post-extractive implants or in a healed site, depending on the width of the available keratinized mucosa. In cases of ridge atrophy, defined as a bone height of < 7.0 mm and/or bone width of < 4.5 mm, implant placement was performed simultaneously with guided bone regeneration (GBR). Otherwise, in cases of severe ridge atrophy, implant placement was performed six months after bone regeneration. Sinus lift procedures were performed using the conventional lateral window technique or by a less invasive transcrestal sinus floor elevation (Crestal Approach Sinus KIT, CAS-KIT, Osstem) in the case of a residual alveolar crest of at least 3 mm (maximum of 8 mm) in height and 6 mm in width distal to the canine, measured on a CBCT scan. In all reconstructive cases, the bone graft material was based on autogenous bone, combined with synthetic hydroxyapatite enriched with magnesium (SINTlife, Finceramica, Faenza, Italy) or with beta-tricalcium phosphate (Q-Oss+, Osstem). A resorbable cross-linked collagen membrane (OssGuide, Osstem) was used to protect the graft material during healing in the case of GBR or the lateral window approach.

In the case of immediate post-extractive implants, residual teeth were extracted as atraumatically as possible. Implant insertion was then planned along the palatal socket wall, about

1.5 mm below the buccal alveolar crest. The residual socket was grafted with corticocancellous heterologous bone, with a graft particle size of 250–1,000 μm (OsteoBiol Gen-Os, TecnoSS, Giaveno, Italy). In the case of delayed implants, socket preservation was performed with the same procedure and the implant was placed four months after healing.

Loading protocols varied based on implant stability and/or individual case requirements. Immediate loading (within 48 h of implant placement) was performed in the case of an implant stability of at least 35 N cm and at the patient's request. Titanium temporary abutments or titanium or zirconia definitive abutments were screwed directly on to the implants or the intermediate abutments (straight or angulated multi-abutments, Osstem) with prosthetic screws tightened to 15 N cm on the day of surgery. Straight or angled multi-abutments (Osstem) were used in the case of multiunit restorations and screw-retained prostheses and/or when there was the need to change the depth or the angle of the implant. Prefabricated, screw-retained or cemented temporary acrylic restorations were trimmed and polished chairside. Partially edentulous patients received nonocclusal temporary restorations. Multiple implants received splinted, metal-reinforced temporary restorations with centric contact and group function, but without any cantilever. If needed, flaps were closed around the abutments. Otherwise, in the case of a bone augmentation procedure or post-extractive implants, a conventional or delayed loading protocol (three to six months after implant placement) was adopted.¹⁷

After implant placement, all of the patients received oral and written recommendations on medication, oral hygiene maintenance and diet. Postoperative antibiotic therapy (1 g of amoxicillin or 300 mg of clindamycin), administered every 12 h for six days, was limited to cases with immediate socket sites, bone grafting or sinus procedures. Analgesics (500 mg of paracetamol plus 30 mg of codeine, or 600 mg of ibuprofen) were administered as needed.

Final restorations were delivered between eight (single or partial crowns and overdentures) and twenty weeks (full arches). Final restorations were either screw-retained or cemented. Cemented restorations were delivered on either stock or customized CAD/CAM abutments. All of the restorations (metal and zirconia) were cemented using a glass ionomer cement (Ketac Cem, 3M ESPE, Neuss, Germany). Any cement

Table 1

Type	Subtype	Implant protocol and location
Conventional preparation		Healed site
Adapted preparation technique	Narrow preparation	Freehand, maxilla required immediate loading, post-extractive implants, poor bone quality
	Halfway preparation	Guided surgery, maxilla, immediate loading
	Osteotome technique	Maxilla, needed to perform bone spreading

remnant was immediately removed using an air–water syringe with the patient’s mouth closed. After 5 min of setting, the patient was clinically and radiographically inspected. Otherwise, CAD/CAM screw-retained restorations were delivered at implant or abutment level. The final abutments and screw-retained frameworks were screwed on at the torque setting recommended by the manufacturer.

The patients that received cemented restorations were inspected again after three to five days. All of the patients were then enrolled in a standard implant recall program. Oral hygiene maintenance was checked and radiographs were taken early after final prosthesis delivery. Occlusion was checked at every appointment. An explanatory case is illustrated in **Figures 1 to 10**.

Outcomes

Primary outcome measures were the success rates of the implants and prostheses, evaluated by an independent assessor. An implant was considered a failure if it presented any mobility, assessed by tapping or rocking the implant head with the metallic handles of two instruments, progressive MBL or infection, and any mechanical complications rendering the implant unusable, although still mechanically stable in the bone. A prosthesis was considered a failure if it needed to be replaced with another prosthesis.

Secondary outcomes were as follows:

- Complications: Any biological (pain, swelling, suppuration, etc.) and/or mechanical (screw loosening, fracture of the framework and/or the veneering material, etc.) complications were evaluated and treated by the same surgeon.
- Marginal bone levels: The levels were assessed using intraoral digital periapical radiographs

(Digora Optime, SOREDEX, Tuusula, Finland; photostimulable phosphor imaging plate, size 2, pixel size of 30 µm, resolution of 17 lp/mm) at the subsequent follow-ups: implant placement (baseline), second-stage surgery, definitive crown delivery and one year after loading. Intraoral radiographs were taken with the paralleling technique by means of a periapical radiograph with a commercially available film holder (Rinn XCP, Dentsply Rinn, Elgin, Ill., U.S.). The radiographs were accepted or rejected for evaluation based on the clarity of the implant threads. All readable radiographs were uploaded to an image analysis software package (DfW 2.8, SOREDEX) that was calibrated using the known length or diameter of the dental implants and displayed on a 24 in. LCD screen (iMac, Apple, Calif., U.S.) and evaluated under standardized conditions (ISO 12646:2004). The marginal bone levels were determined from linear measurements performed by an independent calibrated examiner on each periapical radiograph, from the mesial and distal margin of the implant neck to the most coronal point where the bone appeared to be in contact with the implant.

- Insertion torque. This was recorded at implant placement by the same surgeon (MT) using the iChiropro surgical unit (Bien-Air, Bienne, Switzerland).
- Implant stability quotient (ISQ): The measurements were performed at implant placement and at the six-month follow-up by the surgeon (MT) using resonance frequency analysis (Osstell Mentor device, Osstell, Gothenburg, Sweden).
- Residual alveolar bone quality: This was assessed during surgery by the same surgeon (MT) and classified according to the Lekholm and Zarb classification.

Table 1
Drilling protocols.

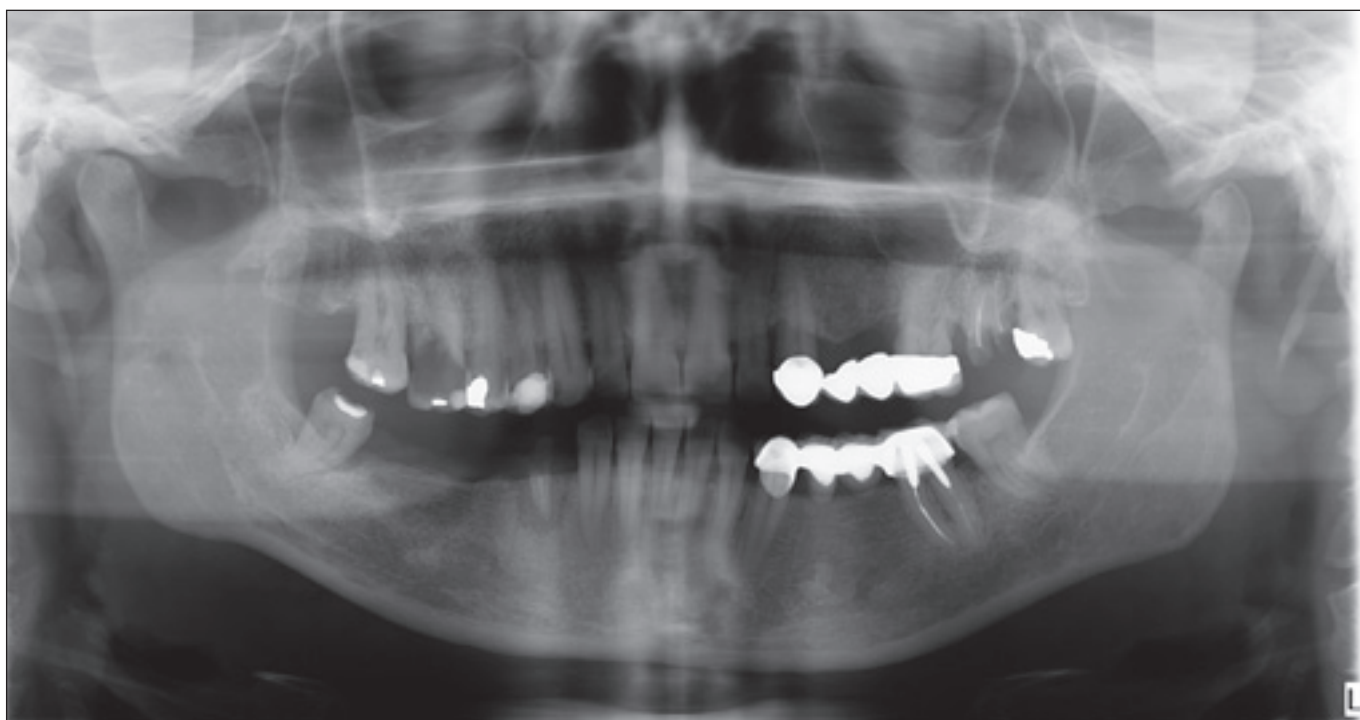


Fig. 1



Fig. 2

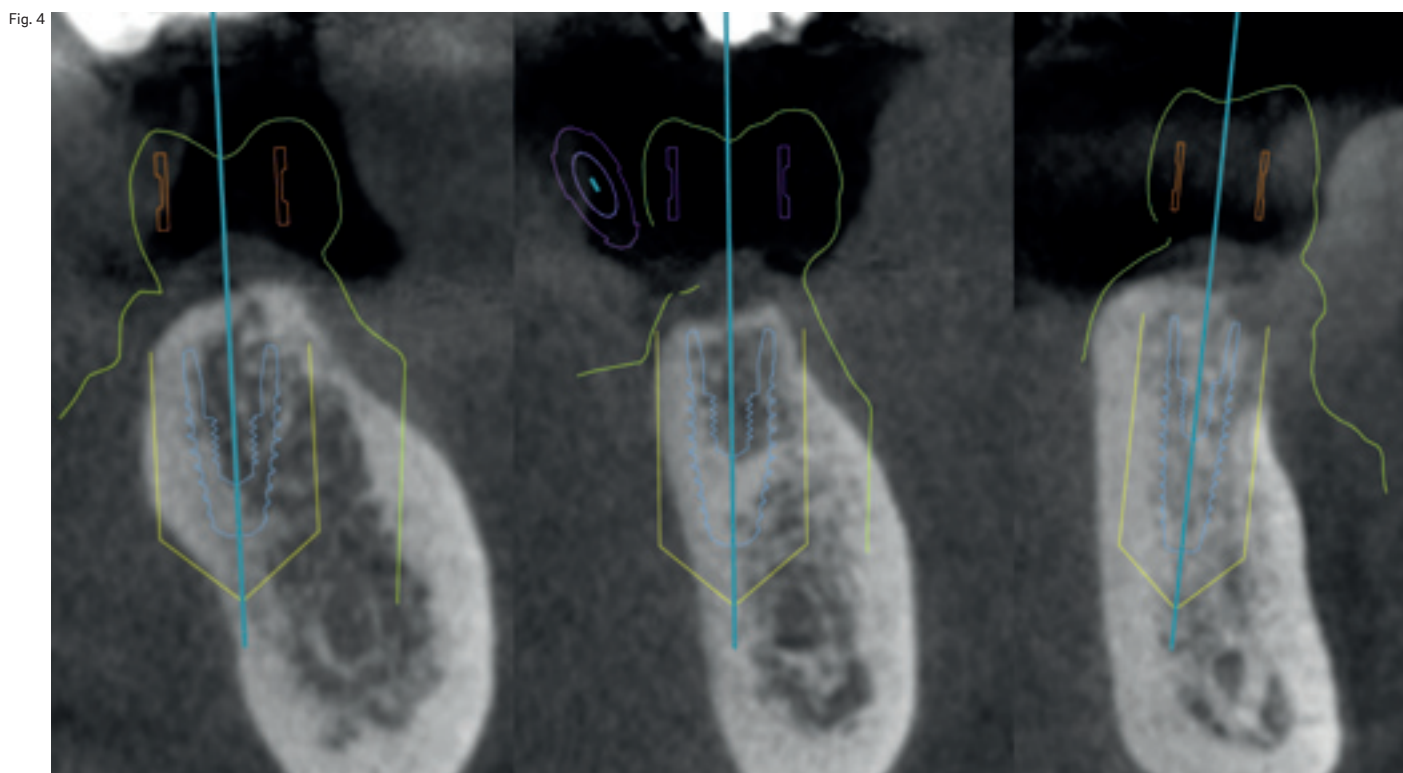
Fig. 1
Preoperative panoramic
radiograph.

Fig. 2
Preoperative intraoral
photograph: lateral view.

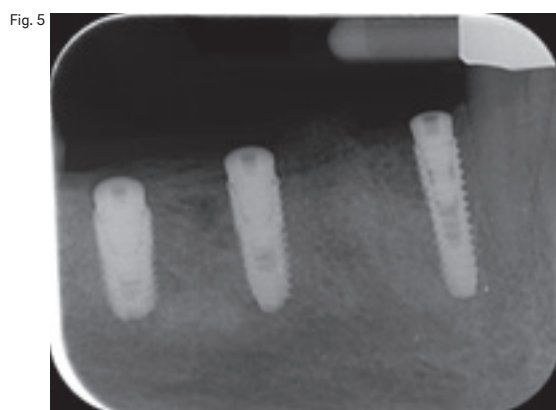
Fig. 3
Preoperative intraoral
photograph: occlusal view.



Fig. 3

**Fig. 4**

Virtual planning. From left to right, teeth #47, 46 and 44.

**Fig. 5**

Periapical radiograph taken after placement of the implants.

confidence interval (CI), whereas ordinal and dichotomous variables are presented as percentages. The implant or the restoration were the statistical units of analysis. Differences in the proportion of patients with prosthesis failures, implant failures and complications (dichotomous outcomes) were compared between the groups using the Fisher exact test. Differences in mean for continuous outcomes (bone level and ISQ) were compared at patient level by independent samples t-tests and one-way analysis of variance, respectively. Comparisons between each time point and the baseline measurements were made by paired tests, in order to detect any changes in marginal periimplant bone levels. All statistical comparisons were conducted at the 0.05 level of significance.

Results

A total of 243 sandblasted and acid-etched bone level implants featuring an 11° Morse taper connection were placed in 90 consecutive patients recruited and treated between September 2014 and December 2015 and followed for at least one year after loading. All of the initially selected patients were included and no patients dropped out of the study. The data of all of the patients were evaluated in the statistical analysis.

Statistical analysis

Patients data were collected in an MS Excel spreadsheet. A statistician with expertise in dentistry analyzed the data and performed all of the statistical analysis using SPSS for Macintosh (Version 22.0; IBM, Chicago, Ill., U.S.). The distributions of continuous variables are given as mean \pm standard deviation, median and 95%

– Thickness of the gingival biotype: This was assessed at the time of surgery using a periodontal probe (PCPUNC156, Hu-Friedy Italy, Milan, Italy) or a tension-free caliper. The gingival biotype was considered thin if the measurement was 1 mm and thick if > 1 mm.



Figs. 6 & 7



Figs. 8 & 9

Fig. 6

Screw-retained temporary restoration placed eight weeks after implant placement.

Fig. 7

Try-in of the zirconia-based frameworks.

Fig. 8

Delivery of the final restoration.

Fig. 9

Intraoral photograph taken one year after delivery of the definitive restoration.

The patients were of both sexes (34 males and 56 females) and had an average age of 53.2 ± 15.4 years (range of 24–81 years). All of the patients were followed up for a minimum period of one year after loading (mean of 17.6 ± 2.5 months; range of 12–24 months). Most of the implants ($n = 208$) were placed in non-smoking patients, while 20 implants were placed in patients who smoked ≤ 10 cigarettes per day and 15 implants in patients who smoked > 10 cigarettes per day. The main implant characteristics are shown in **Table 2**.

Forty-three implants were immediately placed in post-extraction sockets (Type 1),¹⁸ 75 implants were placed 12–16 weeks after a socket preservation procedure (Type 3)¹⁸ and 125 implants were placed late (more than four months after tooth extraction, Type 4).¹⁸ Forty-nine implants were immediately loaded (20.2%) and 76 implants were placed using guided surgery (32.5%). Overall, 172 implants were conventionally placed without bone augmentation. Nineteen implants were placed in conjunction with horizontal GBR using a native collagen membrane and 1:1 ratio of particulated xenograft and autologous bone. Ten implants were placed in conjunction with a transcrestal sinus floor elevation. Three implants were placed with a combination of GBR and transcrestal sinus floor

elevation. Thirty-nine immediate implants were placed in combination with socket preservation procedures.

The overall insertion torque ranged between 15.0 and 45.0 N cm (mean of 42.9 ± 4.8 N cm). Two hundred and three implants (83.5%) were placed at an insertion torque ranging from ≥ 35 to 45 N cm. The definitive restorations were delivered 8 to 20 weeks after second-stage surgery (**Fig. 11**). All of the impressions were taken at implant or abutment level with anatomically customized light-curing acrylic impression trays (Elite LC tray, Zhermack, Badia Polesine, Italy) fabricated on a preliminary cast derived from an irreversible hydrocolloid impression taken with a stock metal impression tray. The impressions were made with plaster (Snow White Plaster No. 2, Kerr, Orange, Calif., U.S.) in the case of edentulous patients or with a polyether material (Impregum Penta, 3M Italia, Milan, Italy) for single and partial restorations.

Overall, 104 single crowns were delivered in 67 patients, 20 fixed partial dentures (FPDs) supported by two to three implants were delivered in 16 patients and the remaining 16 patients received 19 full-arch restorations supported by two to six implants (**Table 3**). Definitive prostheses were screwed on to 168 implants (71 single crowns, 11 FPDs and 13 full-arch resto-

Fig. 10

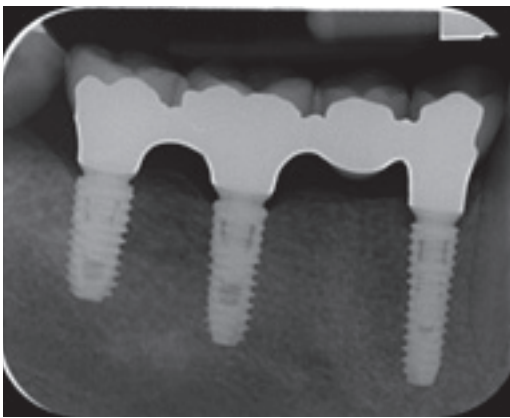


Fig. 10

Periapical radiograph taken one year after delivery of the definitive restoration.

rations) and cemented on to the remaining 61 implants (33 single crowns, nine FPDs and one full-arch restoration). Three patients (six implants) received overdentures on OT Equator attachments (Rhein 83, Bologna, Italy) and two patients (eight implants) received overdentures fully supported by a titanium CAD/CAM bar (New Ancorvis) and OT Equator attachment screwed on the top.

Five implants failed in five patients, resulting in a cumulative implant survival rate of 97.9% at the follow-up one year after loading. All of those implants failed before definitive loading. Two implants were placed in combination with bone augmentation procedures ($p = 0.6310$), one implant was immediately loaded ($p = 1.000$) and two were placed immediately after tooth extraction ($p = 0.2108$). Of these, two implants were placed using guided surgery ($p = 0.6572$). No statistically significant differences were found ($p > 0.05$). Two out of seven implants placed at an insertion torque of < 35 N cm failed ($p = 0.0068$).

No definitive prosthesis failed, resulting in a cumulative prosthetic survival rate of 100%. Four patients experienced one technical complication each, resulting in a cumulative prosthetic success rate of 97.2% at the follow-up one year after loading. One zirconia-based, full-arch framework, delivered on six implants, presented a misfit between the framework and the most distal implant at the try-in appointment. The framework was remade with no further complications. One zirconia-based, full-arch, screw-retained restoration, delivered on six implants, fractured at the bisque bake try-in appointment. The restoration was remade with no further complications. Two patients with a single screw-retained restoration experienced screw loosening. The screws were replaced chairside with no further complications. One patient ex-

perienced pain and swelling up to 3 weeks after implant placement, resulting in a MBL greater than 2 mm. Nevertheless, no further pathological MBL was experienced.

Most of the implants were placed at crest level or a little below. In the case of post-extractive implants, they were placed 1.0–1.5 mm below the buccal bone plate. At the definitive prosthesis delivery, the mean MBL was 0.26 ± 0.25 mm (95% CI: 0.27–0.30). The cumulative mean MBL between implant placement and the one year after loading follow-up was 0.37 ± 0.25 mm (95% CI: 0.26–0.30). The MBL in the interval between the definitive prosthesis delivery and the one year after loading follow-up was 0.11 ± 0.14 mm (95% CI: 0.08–0.10). Overall, 86.8% of the implants ($n = 211$) showed an MBL of ≤ 0.5 mm one year after loading, while only three implants showed an MBL of > 1.0 mm. Two patients were asymptomatic, while a third patient presented with pain without suppuration. This patient was treated with an antibiotic and analgesic until the resolution of the pathology. Eighty-two out of 243 patients (33.7%) reached the two-year follow-up. In this cohort of patients, MBL between the one- and the two-year follow-up was 0.05 ± 0.14 mm (range of 0.0–0.2 mm; 95% CI: -0.01–0.10).

Comparison of MBL and the investigated risk factors found statistically higher MBL for smokers, a thin gingival biotype and GBR. Immediate loading and placement of the definitive abutment on the day of surgery were found to be protective factors, with statistically significantly lower MBL.

Most of the implants ($n = 203$; 83.5%) reached an insertion torque of 45 N cm. The other 40 implants were placed at an insertion torque ranging from ≥ 35 to < 45 N cm ($n = 33$; 13.6%), > 25 to < 35 N cm ($n = 4$; 1.6%) and < 25 N cm ($n = 3$; 1.3%). No statistically significant correlation was found between insertion torque and MBL ($p = 0.3726$).

At implant placement, the mean ISQ value was 71.6 ± 5.5 (range of 45–88); At the six-month follow-up, mean ISQ was 76.7 ± 4.4 (range of 66–89). The difference was statistically significant ($p = 0.0001$).

One hundred and sixty-six implants were placed in bone of Type 1 and 2 quality ($n = 18$). The remaining 77 implants were placed in Type 3 and 4 bone. No statistically significant correlation was found between insertion torque and MBL ($p = 0.4216$).

A thin gingival biotype was associated with higher MBL compared with a thick biotype. The difference was statistically significant

Table 2

Implant characteristics.

Table 3

Type of restoration.

Fig. 11

Timing of implant placement and loading according to the surgical and prosthetic protocol adopted.

Table 4

Marginal bone loss associated with different risk factors.

	7.0 mm	8.5 mm	10.0 mm	11.5 mm	13.0 mm	TOTAL
Osstem TSIII 3.0 mm	–	–	–	–	4	4
Osstem TSIII 3.5 mm	–	2	6	27	10	45
Osstem TSIII 4.0 mm	3	2	17	31	14	67
Osstem TSIII 4.5 mm	3	8	18	8	20	57
Osstem TSIII 5.0 mm	–	1	20	9	–	30
Osstem TSIII 6.0 mm	–	2	11	3	–	16
Osstem TSIII 7.0 mm	–	4	15	5	–	24
TOTAL	6	19	87	83	48	243
	Central incisors	Lateral incisors	Canines	Premolars	Molars	TOTAL
Maxilla	26	7	4	45	41	123
Mandible	–	15	5	42	58	120
TOTAL	26	22	9	87	99	243

Table 2

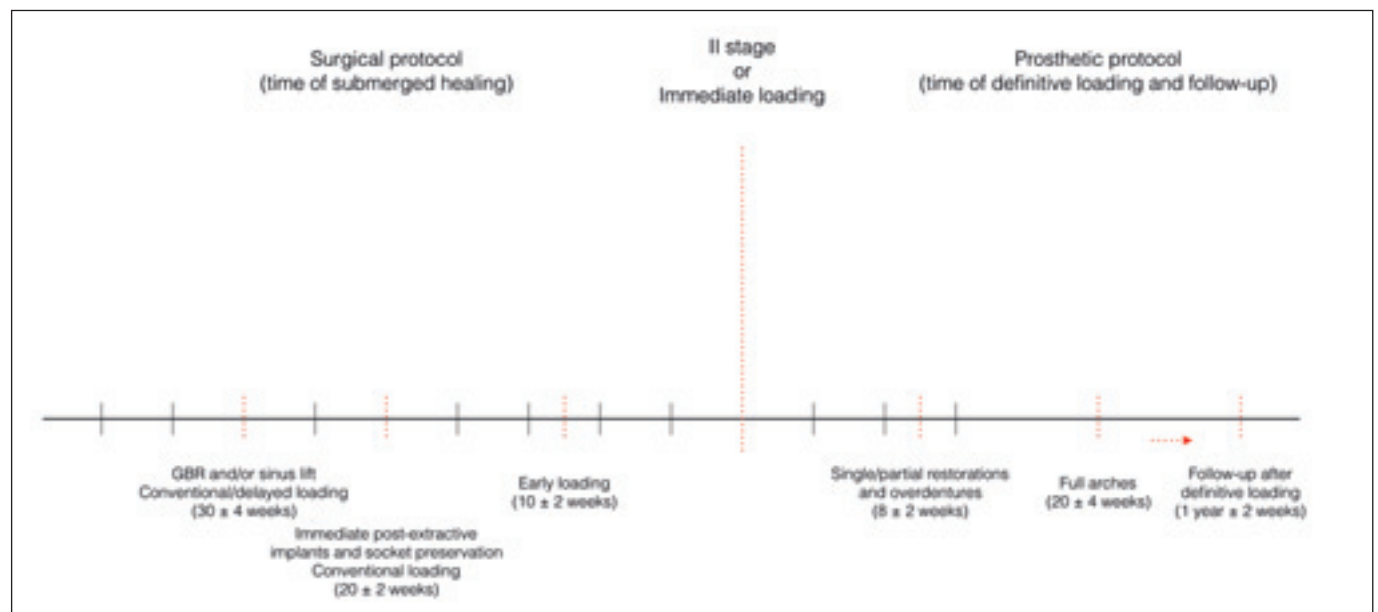


Fig. 11

	Single restoration	Fixed partial denture	Overdenture on OT Equator	Overdenture on titanium bar	Fixed full-arch restoration	TOTAL
Maxilla	46	9	1	–	7	63
Mandible	58	11	2	2	7	80
TOTAL	104	20	3	2	14	143

Table 3

Table 4

						p-value
Implant location	Maxilla (n = 123)		Mandible (n = 120)			
	0.36 ± 0.29		0.38 ± 0.23			0.7961
Timing of implant placement	Post-extractive (n = 43)		Delayed (n = 75)		Healed site (n = 125)	
	0.36 ± 0.29		0.37 ± 0.27		0.38 ± 0.30	0.9643
Type of implant placement	Guided		Conventional freehand			
	0.36 ± 0.24		0.37 ± 0.26			0.8544
Type of prosthesis retention	Cemented (n = 78)		Screwed (n = 165)			
	0.38 ± 0.20		0.36 ± 0.23			0.5135
Type of implant loading	Immediate		Early/conventional			
	0.26 ± 0.20		0.40 ± 0.26			0.0003
Bone augmentation	0 (n = 172)	1 (n = 19)	2 (n = 10)	3 (n = 3)	4 (n = 39)	
	0.35 ± 0.19	0.51 ± 0.50	0.22 ± 0.19	0.23 ± 0.06	0.39 ± 0.27	0.0000
Insertion torque	≤ 35 N cm (n = 40)		≥ 35–45 N cm (n = 203)			
	0.42 ± 0.44		0.36 ± 0.21			0.3726
Bone density	Types 1 and 2 (n = 166)		Types 3 and 4 (n = 77)			
	0.36 ± 0.23		0.39 ± 0.31			0.4216
Smoking	Nonsmoker (n = 222)		Smoker, ≥ 10 cigarettes per day (n = 21)			
	0.35 ± 0.22		0.48 ± 0.38			0.0098
Immediate abutment	Yes (n = 26)		No (n = 217)			
	0.25 ± 0.19		0.38 ± 0.26			0.0113
Gingival biotype	Thin (n = 78)		Thick (n = 165)			
	0.43 ± 0.27		0.34 ± 0.25			0.0307

($p = 0.0307$). All of the radiographic comparisons are reported in **Table 4**.

Discussion

The aim of this prospective open-cohort study was to investigate, over a 1 year after loading period, the implant survival and success rates of sandblasted and acid-etched bone level implants featuring an 11° Morse taper connection placed in private practice, and to evaluate the physiological marginal bone remodeling among subgroups of exposed and unexposed subjects. The main limitation of the present study was the short follow-up period. Nevertheless, one year after loading is sufficient to evaluate the physiological marginal bone remodeling that was the main topic of this research.

In the present study, five out of 243 implants failed over a period of one year after loading, resulting in a cumulative implant survival rate of 97.9%. No definitive prosthesis failed. One biological and four technical complications were experienced, resulting in a cumulative prosthetic and implant success rate of 97.2 and 99.6%, respectively.

The major clinical conclusion of the present research was that the physiological marginal bone remodeling using Osstem TSIII implants (Osstem) was 0.37 mm within one year after loading, independent of the surgical and prosthetic protocols. Subgroup analysis showed that smoking, a thin tissue biotype and GBR were associated with a statistically significantly higher MBL. This supports Sgolastra et al.'s conclusion that smoking seems to be positively associated with higher MBL, implant failure and risk of periimplantitis.¹⁹

The results of the present study are in agreement with a recent systematic review and meta-analysis that showed that implants placed with an initially thicker periimplant soft tissue have less radiographic MBL in the short-term follow-up.²⁰ The results of this study also demonstrated that implants placed with GBR are as successful as implants placed into sites with pristine bone. In the present study, the mean MBL experienced around the implants placed in regenerated bone was slightly higher than that of the implants placed in nongrafted sites. No strong evidence is associated with higher MBL and GBR procedures. Nevertheless, data reported in the present study are consistent with, or slightly lower than, that reported in previous studies.²¹

Immediate loading and the placement of a definitive abutment at implant insertion and never removed have been proven to reduce MBL.^{22,23} A possible explanation of this phenomenon could be that most of the immediately loaded implants were placed without a flap, using guided surgery, and received the definitive abutment on the day of surgery, minimizing MBL.

High primary implant stability is considered one of the main factors necessary for achieving a predictable high success rate.^{24–28} Nevertheless, there is no consensus as to the ideal insertion torque required to prevent implant failure. In the present study, two out of seven implants placed at an insertion torque of < 35 N cm failed, reaching a statistically significant difference. In the study, 83.5% of the implants were placed at an insertion torque of 45 N cm. The drilling protocol was customized according to the bone density. Conventional preparation was performed in healed sites with a bone density of Type 2 or 3.²⁰ Narrow or halfway adapted preparations were performed in the case of post-extractive implants and poor bone quality, using freehand or guided surgery, respectively. Finally, the osteotome technique was performed only in the maxilla, in order to perform bone spreading.

Conclusion

Low implant failure and physiological marginal bone remodeling of 0.37 mm within one year after loading can be expected using Osstem TSIII implants in the daily practice. Smoking, GBR and a thin tissue biotype were associated with higher MBL, while immediate loading and placement of the definitive abutment on the day of surgery reduced the MBL.

Competing interests

The first author (MT) is the Research Project Manager at Osstem AIC, Italy. However, this research was self-supported. Hence, the authors declare that they have no competing interests.

Acknowledgments

Dr. Marco Tallarico wishes to thank Ms. Gianina Bizduna and Stephany Zambrano for their important clinical assistance.

References

- Roos J, Sennerby L, Lekholm U, Jemt T, Gröndahl K, Albrektsson T. A qualitative and quantitative method for evaluating implant success: a 5-year retrospective analysis of the Brånemark implant. → *Int J Oral Maxillofac Implants*. 1997 Jul-Aug;12(4):504–14.
- Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. → *Int J Oral Maxillofac Implants*. 1986 Summer;1(1):11–25.
- Misch CE, Perel ML, Wang HL, Sammartino G, Galindo-Moreno P, Trisi P, Steigmann M, Rebaudi A, Palti A, Pikos MA, Schwartz-Arad D, Choukroun J, Gutierrez-Perez JL, Marenzi G, Valavanis DK. Implant success, survival, and failure: the International Congress of Oral Implantologists (ICOI) Pisa Consensus Conference. → *Implant Dent*. 2008 Mar;17(1):5–15.
- Papaspyridakos P, Chen CJ, Singh M, Weber HP, Gallucci GO. Success criteria in implant dentistry: a systematic review. → *J Dent Res*. 2012 Mar;91(3):242–8.
- Nevins M, Nevins ML, Camelo M, Boyesen JL, Kim DM. Human histologic evidence of a connective tissue attachment to a dental implant. → *Int J Periodontics Restorative Dent*. 2008 Apr;28(2):111–21.
- Cochran DL, Obrecht M, Weber K, Dard M, Bosshardt D, Higginbottom FL, Wilson TG Jr, Jones AA. Biologic width adjacent to loaded implants with machined and rough collars in the dog. → *Int J Periodontics Restorative Dent*. 2014 Nov-Dec;34(6):773–9.
- Jung YC, Han CH, Lee KW. A 1-year radiographic evaluation of marginal bone around dental implants. → *Int J Oral Maxillofac Implants*. 1996 Nov-Dec;11(6):811–8.
- Galindo-Moreno P, Leon-Cano A, Ortega-Oller I, Monje A, O'Valle F, Catena A. Marginal bone loss as success criterion in implant dentistry: beyond 2 mm. → *Clin Oral Implants Res*. 2015 Apr;26(4):e28–34.
- Alfonsi F, Borgia V, Barbato L, Tonelli P, Giammarinaro E, Marconcini S, Romeggio S, Barone A. The clinical effects of insertion torque for implants placed in healed ridges: a two-year randomized controlled clinical trial. → *J Oral Science Rehabilitation*. 2016 Dec;2(4):62–73.
- Bahat O, Sullivan RM. Parameters for successful implant integration revisited part II: algorithm for immediate loading diagnostic factors. → *Clin Implant Dent Relat Res*. 2010 May;12 Suppl 1:e13–22.
- Quirynen M, Naert I, van Steenberghe D. Fixture design and overload influence marginal bone loss and fixture success in the Brånemark system. → *Clin Oral Implants Res*. 1992 Sep;3(3):104–11.
- Harrel SK, Nunn ME. The effect of occlusal discrepancies on periodontitis. II. Relationship of occlusal treatment to the progression of periodontal disease. → *J Periodontol*. 2001 Apr;72(4):495–505.
- Canullo L, Tallarico M, Radovanovic S, Delibasic B, Covani U, Rakic M. Distinguishing predictive profiles for patient-based risk assessment and diagnostics of plaque induced, surgically and prosthetically triggered periimplantitis. → *Clin Oral Implants Res*. 2016 Oct;27(10):1243–50.
- Tallarico M, Monje A, Wang HL, Galindo Moreno P, Khanari E, Canullo L. A systematic review on the definition of periimplantitis: limits related to the various diagnoses proposed. → *J Oral Science Rehabilitation*. 2016 Dec;2(4):42–53.
- American Academy of Periodontology. Peri-implant mucositis and peri-implantitis: a current understanding of their diagnoses and clinical implications. → *J Periodontol*. 2013 Apr;84(4):436–43.
- Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. → *J Clin Epidemiol*. 2008 Apr;61(4):344–9.
- Cochran DL, Morton D, Weber HP. Consensus statements and recommended clinical procedures regarding loading protocols for endosseous dental implants. → *Int J Oral Maxillofac Implants*. 2004;19 Suppl:109–13.
- Elian N, Cho SC, Froum S, Smith RB, Tarnow DP. A simplified socket classification and repair technique. → *Pract Proced Aesthet Dent*. 2007 Mar;19(2):99–104.
- Sgolastra F, Petrucci A, Severino M, Gatto R, Monaco A. Smoking and the risk of peri-implantitis. A systematic review and meta-analysis. → *Clin Oral Implants Res*. 2015 Apr;26(4):e62–7.
- Suárez-López Del Amo F, Lin GH, Monje A, Galindo-Moreno P, Wang HL. Influence of soft tissue thickness on peri-implant marginal bone loss: a systematic review and meta-analysis. → *J Periodontol*. 2016 Jun;87(6):690–9.
- Meloni SM, Jovanovic SA, Urban I, Canullo L, Pisano M, Tallarico M. Horizontal ridge augmentation using GBR with a native collagen membrane and 1:1 ratio of particulated xenograft and autologous bone: a 1-year prospective clinical study. → *Clin Implant Dent Relat Res*. 2017 Feb;19(1):38–45.
- Engelhardt S, Papacosta P, Rathe F, Özen J, Jansen JA, Junker R. Annual failure rates and marginal bone-level changes of immediate compared to conventional loading of dental implants. A systematic review of the literature and meta-analysis. → *Clin Oral Implants Res*. 2015 Jun;26(6):671–87.
- Canullo L, Bignozzi I, Cocchetto R, Cristalli MP, Iannello G. Immediate positioning of a definitive abutment versus repeated abutment replacements in post-extractive implants: 3-year follow-up of a randomised multicentre clinical trial. → *Eur J Oral Implantol*. 2010 Winter;3(4):285–96.
- Meloni SM, Tallarico M, Pisano M, Khanari E, Canullo L. Immediate loading of fixed complete denture prosthesis supported by 4-8 implants placed using guided surgery: a 5-year prospective study on 66 patients with 356 implants. → *Clin Implant Dent Relat Res*. 2017 Feb;19(1):195–206.
- Tallarico M, Meloni SM, Canullo L, Caneva M, Polizzi G. Five-year results of a randomized controlled trial comparing patients rehabilitated with immediately loaded maxillary cross-arch fixed dental prosthesis supported by four or six implants placed using guided surgery. → *Clin Implant Dent Relat Res*. 2016 Oct;18(5):965–72.
- Meloni SM, De Riu G, Pisano M, Dell'aversana Orabona G, Piombino P, Salzano G, Quarato D, Riccardi E, Belli E, Ungari C. Computer-assisted implant surgery and immediate loading in edentulous ridges with dental fresh extraction sockets. Two years results of a prospective case series study. → *Eur Rev Med Pharmacol Sci*. 2013 Nov;17(21):2968–73.
- Meloni SM, De Riu G, Pisano M, Cattina G, Tullio A. Implant treatment software planning and guided flapless surgery with immediate provisional prosthesis delivery in the fully edentulous maxilla. A retrospective analysis of 15 consecutively treated patients. → *Eur J Oral Implantol*. 2010 Autumn;3(3):245–51.
- Pozzi A, Tallarico M, Moy PK. Immediate loading with a novel implant featured by variable-threaded geometry, internal conical connection and platform shifting: three-year results from a prospective cohort study. → *Eur J Oral Implantol*. 2015 Spring;8(1):51–63.

Authors must adhere to the following guidelines

Informed consent

Patients have a right to privacy that should not be violated without informed consent. Identifying information, including patients' names, initials or hospital numbers, should not be provided in the manuscript or visual material unless the information is essential for scientific purposes and the patient (or parent or guardian) has given written informed consent for publication. Informed consent for this purpose requires that an identifiable patient be shown the manuscript to be published. Authors should disclose to these patients whether any potential identifiable material might be available via the Internet as well as in print after publication. Nonessential identifying details should be omitted. Informed consent should be obtained if there is any doubt that anonymity can be maintained. For example, masking the eye region in photographs of patients is inadequate protection of anonymity. If identifying characteristics are altered to protect anonymity, authors should provide assurance that alterations do not distort scientific meaning. **When informed consent has been obtained, it should be indicated in the manuscript.**

Human and animal rights

When reporting experiments on human subjects, authors should indicate whether the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Declaration of Helsinki of 1975, as revised in 2013 (www.wma.net/en/30publications/10policies/b3/index.html). If doubt exists whether the research was conducted in accordance with the Declaration of Helsinki, the authors must explain the rationale for their approach, and demonstrate that the institutional review body explicitly approved the doubtful aspects of the study. When reporting experiments on animals, authors should indicate whether institutional and national standards for the care and use of laboratory animals were followed. Further guidance on animal research ethics is available from the International Association of Veterinary Editors' Consensus Author Guidelines on Animal Ethics and Welfare (www.veteditors.org/consensus-author-guidelines-on-animal-ethics-and-welfare-for-editors).

Preparing the manuscript text

General

The manuscript must be written in U.S. English. The main body of the text, excluding the title page, abstract and list of captions, but including the references, may be a maximum of 4,000 words. Exceptions may be allowed with prior approval from the publisher.

Authors will have the opportunity to add more information regarding their article, as well as post videos, present a webinar and blog on the DT Science website.

It is preferred that there be no more than six authors. If more authors have participated in the study, the contribution of each author must be disclosed at the end of the document.

Title

The title should not exceed 35 characters. Capitalize only the first word and proper nouns in the title. Please include a running title as well.

Author information

The following information must be included for each author:

- Full author name(s)
- Full affiliation (department, faculty, institution, town, country).

For the corresponding author, the following information should be included in addition:

- Full mailing address
- Email address.

Abstract and keywords

The manuscript must contain an abstract and a minimum of 3, maximum of 6 keywords. The abstract should be self-contained, not cite any other work and not exceed 250 words. It should be structured into the following separate sections: objective, materials and methods, results, conclusion and keywords. For case reports, the sections should be background, case presentation, conclusion and keywords.

Structure of the main text

The body of the manuscript must be structured as follows:

- Introduction (no subheadings)
- Materials and methods
- Results
- Discussion
- Conclusion.

Competing interests

Authors are required to declare any competing financial or other interests regarding the article submitted. Such competing interests are to be stated at the end of manuscript before the references. If no competing interests are declared, the following will be stated: "The authors declare that they have no competing interests."

Acknowledgments

Acknowledgments (if any) should be brief and included at the end of the manuscript before the references, and may include supporting grants.

References

Authors are responsible for ensuring that the information for each reference is complete and accurate. All references must be cited within the manuscript. References appearing in the list but not in the manuscript will be removed. In-text citation should follow the citation–sequence format (e.g., “as discussed by Haywood et al.¹⁵”) using superscript numbers placed after the punctuation in the relevant sentence. The references must be numbered consecutively.

The reference list must be numbered and the references provided in order of appearance. For the reference list, the journal follows the citation style stipulated in *Citing medicine: the NLM style guide for authors, editors, and publishers*. The guidelines may be viewed and downloaded free of charge at

www.ncbi.nlm.nih.gov/books/NBK7256/

The reference list may not exceed 50 references.

List of captions

Please provide the captions for all visual material at the end of the manuscript.

Abbreviations

Abbreviations should be used sparingly and defined when first used. The abstract and the main manuscript text should be regarded as separate documents in this regard.

Typography

- Use Times New Roman regular with a font size of 12 pt.
- Use double line spacing with blank lines separating sections and paragraphs.
- Type the text unjustified and do not apply hyphenation at line breaks.
- Number all of the pages.
- Use endnotes if necessary, but not footnotes.
- Greek and other special characters may be included.

Preparing the visual material

Requirements for images

Each image should be supplied separately and the following formats are accepted: PSD, TIFF, GIF and JPEG. The image must have a resolution of 300 dpi and must be no smaller than 6 cm × 6 cm.

Please number the images consecutively throughout the article by using a new number for each image. If it is imperative that certain images be grouped to-

gether, then use lowercase letters to designate these in a group (e.g., “Figs. 2a–c”).

Place the references to the images in your article wherever they are appropriate, whether in the middle or at the end of a sentence. Provide a caption for each image at the end of your article.

Requirements for tables

Each table should be supplied separately and in Microsoft Word format. Tables may not be embedded as images and no shading or color is to be used.

Tables should be cited consecutively in the manuscript. Place the references to the tables in your article wherever they are appropriate, whether in the middle or at the end of a sentence. Every table must have a descriptive caption, and if numerical measurements are given the units should be included in the column headings.

Supplements/supporting material

DT Science allows an unlimited amount of supporting material (such as datasets, videos or other additional information) to be uploaded. This material should be presented succinctly (in English). The author bears full responsibility for the content. Color, animated multimedia presentations, videos and so on are welcome and published at no additional cost to the author or reader. Please refer briefly to such material in the manuscript where appropriate (e.g., as an endnote).

Submit your research and clinical articles to

Dr. Daniele Botticelli at
daniele.botticelli@gmail.com

For all other requests, contact

Nathalie Schüller at
n.schueller@dental-tribune.com
T +49 341 4847 4136

Dental Tribune International Publishing Group
Holbeinstr. 29
04229 Leipzig
Germany

www.dtscience.com
www.dental-tribune.com

International office

Dental Tribune International
Holbeinstr. 29
04229 Leipzig
Germany

T +49 341 4847 4302
F +49 341 4847 4173

info@dental-tribune.com
www.dental-tribune.com



Publishing team

Publisher/President/CEO

Torsten R. Oemus
t.oemus@dental-tribune.com

Managing Editor

Nathalie Schüller
n.schueller@dental-tribune.com

Concept & design

Rhowerk
www.rhowerk.de

Chief Technology Officer

Serban Veres
serbanveres@gmail.com

Copy editors

Sabrina Raaff
sabrina@greenbadger.co.za

Hans Motschmann
h.motschmann@oemus-media.de

International administration

Chief Financial Officer

Dan Wunderlich
d.wunderlich@dental-tribune.com

Marketing Services

Nadine Dehmel
n.dehmel@dental-tribune.com

Sales Services

Nicole Andrá
n.andrae@dental-tribune.com

Executive Producer

Gernot Meyer
g.meyer@dental-tribune.com

Copyright regulations

The *Journal of Oral Science & Rehabilitation* is published quarterly by Dental Tribune International (DTI). The journal and all articles and illustrations contained therein are protected by copyright. Any utilization without the prior consent of the authors, editor and publisher is prohibited and liable to prosecution. This applies in particular to the duplication of copies, translations, microfilms, and storage and processing in electronic systems. Reproductions, including extracts, may only be made with the permission of the publisher. Given no statement to the contrary, any submissions to the editorial department are understood to be in agreement with full or partial publishing of said submission. The editorial department reserves the right to check all submitted articles for formal errors and factual authority, and to make amendments if necessary. Articles bearing symbols other than that of the editorial department, or that are distinguished by the name of the author, represent the opinion of the afore-mentioned, and do not have to comply with the views of DTI. Responsibility for such articles shall be borne by the author. Responsibility for advertisements and other specially labeled items shall not be borne by the editorial department. Likewise, no responsibility shall be assumed for information published about associations, companies and commercial markets. All cases of consequential liability arising from inaccurate or faulty representation are excluded. The legal domicile is Leipzig, Germany.

Printer

Löhner Druck | Handelsstr. 12 | 04420 Markranstädt | Germany

Editorial board

Editor-in-Chief

Ugo Covani, Pisa and Camaiore, Italy

Co-editors

Daniele Botticelli, Rimini, Italy
José Luis Calvo Guirado, Murcia, Spain
Miguel Peñarrocha Diago, Valencia, Spain

Associate editors

Antonio Barone, Geneva, Switzerland
Luigi Canullo, Rome, Italy
Rafael Arcesio Delgado Ruiz, Stony Brook, N.Y., U.S.
David Peñarrocha Oltra, Valencia, Spain

Scientific advisers

Pablo Galindo Moreno, Granada, Spain
Georgios Romanos, Stony Brook, N.Y., U.S.
Giovanni Serino, Borås, Sweden

Statistical advisers

Marco Tallarico, Sassari, Italy
Francesco Tessoro, Mattarello, Italy

Executive board

Daniele Botticelli, Rimini, Italy
Luigi Canullo, Rome, Italy
Torsten R. Oemus, Leipzig, Germany

Board of reviewers

Marcus Abboud, Stony Brook, N.Y., U.S.
Marco Álvarez, Mexico City, Mexico
Conrado Aparicio, Minneapolis, Minn., U.S.
Shunsuke Baba, Osaka, Japan
Franco Bengazi, Brescia, Italy
Andrea Edoardo Bianchi, Milan, Italy
Manuel Bravo Pérez, Granada, Spain
Eribero Bressan, Padua, Italy
Marco Caneva, Trieste, Italy
Juan Carlos De Vicente Rodríguez, Oviedo, Spain
Stefan Fickl, Würzburg, Germany
Joseph Fiorellini, Philadelphia, Pa., U.S.
Abel García García, Santiago de Compostela, Spain
Gerardo Gómez Moreno, Granada, Spain
Federico Hernández Alfaro, Barcelona, Spain
Carlos Larrucea Verdugo, Talca, Chile
Baek-Soo Lee, Seoul, South Korea
Dehua Li, Xi'an, China
Francesco Guido Mangano, Milan, Italy
Aleksa Markovic, Belgrade, Serbia
José Eduardo Maté Sánchez de Val, Murcia, Spain
Silvio Meloni, Sassari, Italy
Eitan Mijiritsky, Tel Aviv, Israel
Alberto Monje, Ann Arbor, Mich., U.S.
Yasushi Nakajima, Osaka, Japan
Ulf Nannmark, Gothenburg, Sweden
Wilson Roberto Poi, Araçatuba, Brazil
Rosario Prisco, Foggia, Italy
Alessandro Quaranta, Dunedin, New Zealand
Maria Piedad Ramírez Fernández, Murcia, Spain
Idelmo Rangel García, Araçatuba, Brazil
Fabio Rossi, Bologna, Italy
Hector Sarmiento, Philadelphia, Pa., U.S.
Nikola Saulacic, Bern, Switzerland
Alessandro Scala, Pesaro, Italy
Carlos Alberto Serrano Méndez, Bogotá, Colombia
Andrew Tawse-Smith, Dunedin, New Zealand
Cemal Ucer, Manchester, U.K.
Joaquín Urbizo Velez, La Habana, Cuba

€50/issue of the Journal
(4 issues/year; including
VAT and shipping costs,
for a total of €200/year)

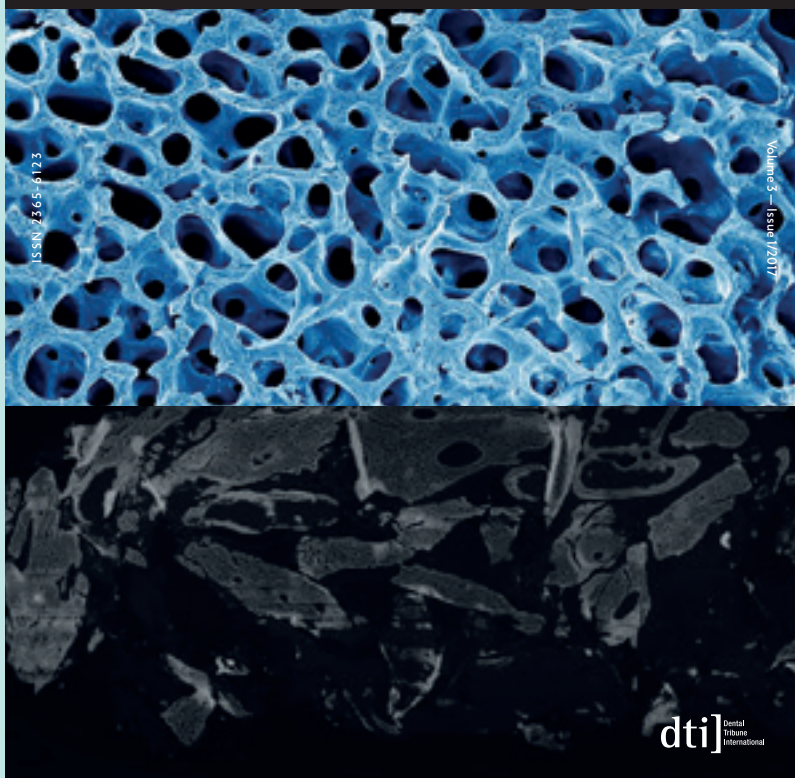
Your subscription will be
renewed automatically
every year until a written
cancellation is sent
six weeks prior to the
renewal date to

Dental Tribune
International GmbH,
Holbeinstr. 29, 04229
Leipzig, Germany.

Journal of

Oral Science & Rehabilitation

Journal for periodontology, implant dentistry,
dental prosthodontics and maxillofacial surgery



Subscribe Now!

Shipping address

City

Country

Phone

Fax

Signature

Date

☐ PayPal | subscriptions@dental-tribune.com

☐ Credit card

Credit card number

Expiration date

Security code

fax: +49 341 4847 4173 | email: subscriptions@dental-tribune.com

dti Dental
Tribune
International



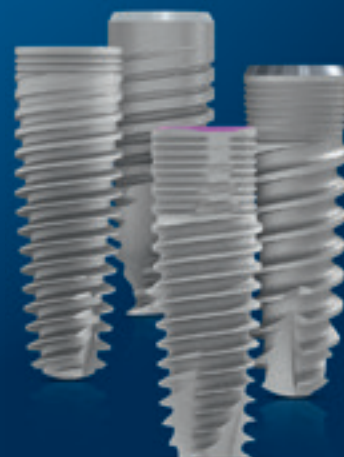
ADMED
com

To learn more about our innovative products,
please visit us at IDS, Cologne, March 21-25:
Hall 4.1, Aisle B-030/D-039

EXPERIENCE THE GLOBAL SUCCESS
MAKE IT SIMPLE

mis[®]

MIS is a global leader in the development and production of advanced products and innovative solutions aimed to simplify implant dentistry. Successfully sold and distributed in over 65 countries worldwide, MIS provides unparalleled service to our customers. To learn more, visit our website: www.mis-implants.com





- ISO: 8, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 70, 80, 90, 100, 110, 120, 130, 140
- Non-Standardized (Accessory sizes): XF, FF, MF, F, FM, M, ML, L, XL
- Special Taper Points: 04, 06

گوتا فقط متا

- ✓ پرفروش ترین در جهان
- ✓ انعطاف پذیری بسیار بالا در حین کار
- ✓ بی رقیب در قیمت و کیفیت
- ✓ رادیو اپستی عالی
- ✓ مناسب جهت پر کردن کانال به روش تراکم جانبی و عمودی
- ✓ با بهترین بسته بندی ضد ریزش برای کاربری آسان



کن کاغذی

موجود در انواع سایزها با قدرت جذب بالا، استریل و فاقد لینت
در بسته بندی ۲۰۰ عددی کشوئی ضد ریزش