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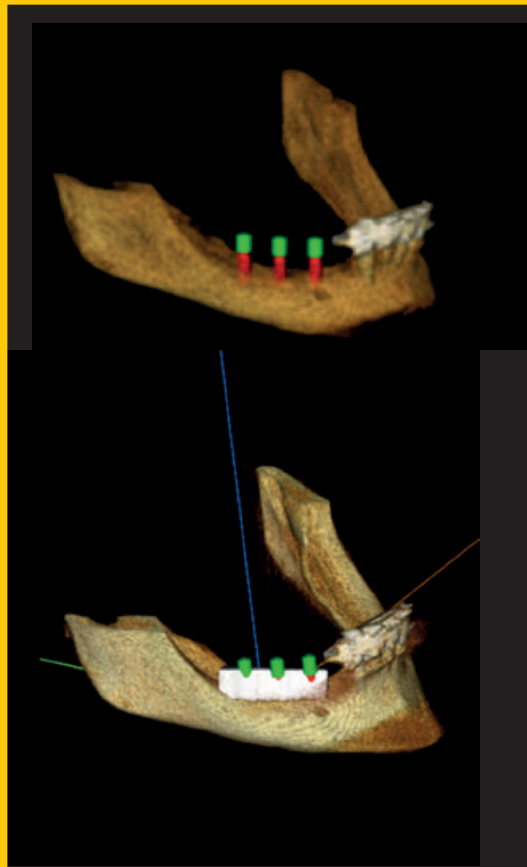
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Dentistry, *quo vadis*?

As a professional who has devoted my life to dentistry, treating patients, teaching at a university and contributing to my branch of science, I am growing older, gaining experience and analyzing things from different perspectives. After reflecting on and evaluating my more than 25 years of clinical practice, my role as a teacher and mentor to many students, and my current knowledge, I wonder where to from here.

The knowledge in dentistry is changing rapidly based on different premises. The academic institution has made it clear that randomized clinical trials and meta-analyses are at the top of the pyramid of scientific knowledge. There are some journals that rarely accept a manuscript that does not have in its title the magic words “randomized clinical trial”; yet, there are thousands of systematic reviews and meta-analyses on any meaningless aspect of the literature, meta-analysis based only on those randomized clinical trials. Sometimes, journals publish some meta-analyses based only on one or two manuscripts, which is simply a repetition of the same conclusion of the manuscript. Interestingly, there is even a coincidence in the authorship of both manuscripts, a kind of misconduct in science.

When analyzing the bibliometric aspects of our science, in the context of science, dentistry is almost nothing in comparison with other disciplines; it is like a small star in the Milky Way. However, we are trying to resemble the disciplines of older brothers, forgetting the strength of our own science. As dentists, we are required to contribute the best for patients, reinforcing clinical aspects, based on knowledge and evidence. We are health care providers. Our editors, journals and reviewers, and we ourselves must become aware of this, support deeper clinical research that undoubtedly contributes to better feedback in all fields for our patients and avoid many of those manuscripts that are only aimed at greater impact factors, *h*-indexes or citations, increasing the ego and visibility of some authors and institutions, with no benefit for the real readers of our journals and the final destination of our research: our patients.

As a professor, as a researcher, assuming my share of *mea culpa*, I begin to be fed up with diving into the literature looking for important manuscripts that bring light and knowledge to our community, but remaining unsatisfied. I begin to wonder, dentistry, *quo vadis*?

Dr. Pablo Galindo Moreno
Associate editor and scientific adviser

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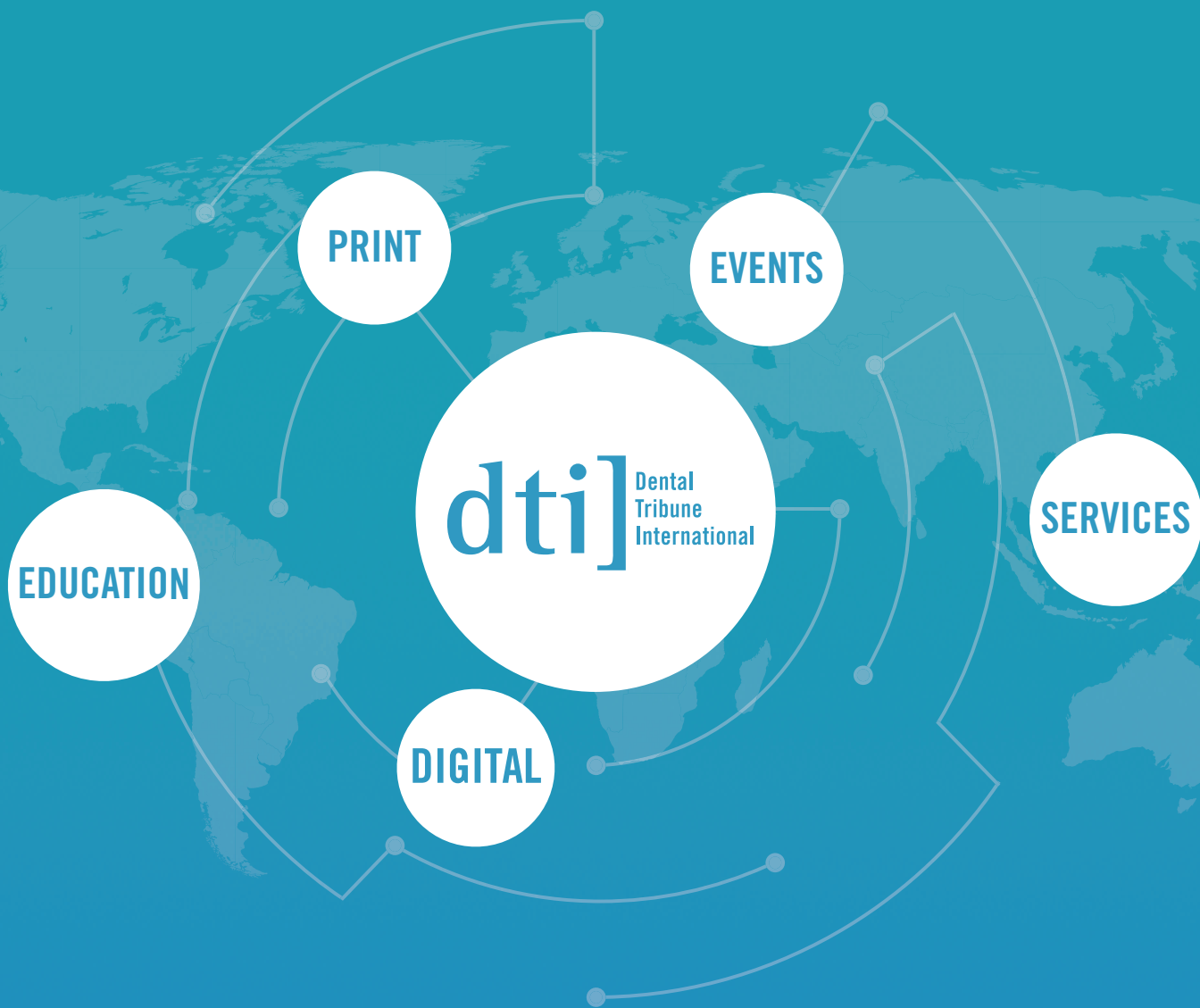
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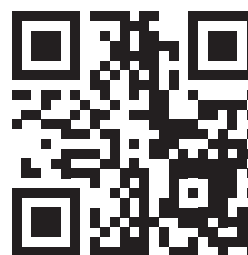
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Subcutaneous emphysema after a direct sinus lift: A case report

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Materials and methods

A 52-year-old patient underwent a maxillary direct sinus lift for the future placement of implants in the posterior area. A few hours after the surgery, the patient repeatedly sneezed with his mouth closed 3 times, immediately causing a large swelling in the left periorbital area that prevented him from opening the eye. After clinical and radiographic examination, it was determined that it was a subcutaneous emphysema. The prescribed treatment was antibiotics.

Conclusion

Subcutaneous emphysema is a benign and usually self-limited entity, which usually resolves spontaneously. Most authors agree on the use of turbines as the most frequent etiology. Other reasons, however, have also been reported in the literature, such as endodontic treatment and the use of dental lasers. The main clinical manifestations that aided us in establishing a correct differential diagnosis were swelling without redness, edema and crepitating palpation of the soft tissue. In general, patients do not report pain, but at worst a slight discomfort due to swelling.

Keywords

Subcutaneous emphysema; periorbital edema; orbital emphysema; complications; sinus floor elevation.

Abstract

Objective

Subcutaneous oral emphysema is defined as penetration of pressurized air into the tissue spaces. One possible means of air entry is through the bone window made during a direct sinus lift. There are only 3 cases published in the literature of subcutaneous emphysema with this etiology. It is important that the dentist carefully instruct the patient about the post-surgical protocol that must be carried out to reduce the risk of this complication.

Introduction

Subcutaneous emphysema is defined as the penetration of air pressure into tissue spaces.^{1–8} It is a complication that has been described in the literature for many years. In 1995, Heyman and Babayof reviewed the literature from 1960 to 1993 on emphysematous complications in dental treatment.¹

Subcutaneous emphysema does not occur regularly, but it is important to control to avoid complications such as infections that can be harmful to the patient.⁹

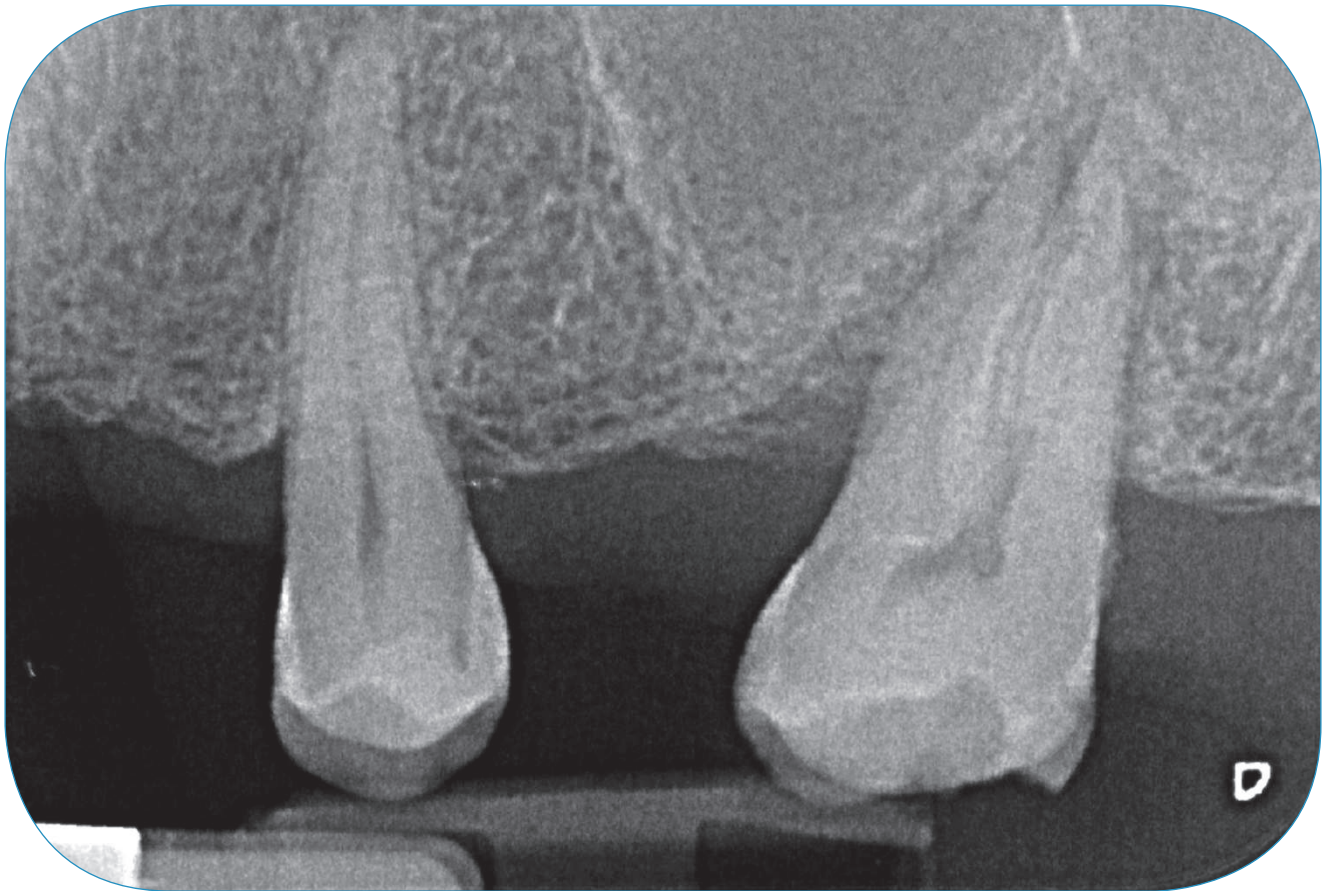


Fig. 1

The condition is usually the result of treatment with high-speed surgical drills and compressed air syringes during restorative and endodontic procedures.⁵ However, in the present case, periorbital edema was observed after several hours of a sinus floor elevation, which makes this case report interesting. There are not many cases reported in the literature about this etiology, which is mostly related to post-surgical maneuvers of the patient (sneezing while keeping the mouth closed, blowing the nose, playing wind instruments).¹⁰ The objective of this clinical case is to demonstrate to oral and maxillofacial surgeons the possibility of orbital and periorbital emphysema after an intervention in the maxillary sinus, as well as the procedure to follow in the case of this complication.

Study design and ethical aspects

The present study is a case report. The patient was willing and fully capable of complying with the clinical procedures, and a written informed consent was obtained 7 days before the initiation of treatment.

Case report

The patient was 52 years old and a nonsmoker. He attended the periodontics department (University of Valencia, Valencia, Spain) for checks and controls periodically. The Department of Oral Surgery and Implantology, University of Valencia, Valencia, Spain, requested restoration of his missing teeth with implants.

The third and second molars had been extracted about 20 months before the observation. The patient was willing to have the right maxillary posterior area rehabilitated with a fixed prosthesis (**Figs. 1 & 2**).

The oral rehabilitation plan called for the placement of an implant 10 mm long and 4 mm wide distal to the maxillary second left premolar. In the right maxilla, an atraumatic sinus lift was sufficient.

The residual height of the bone in the left maxilla was less than 5 mm, which was evaluated by cone

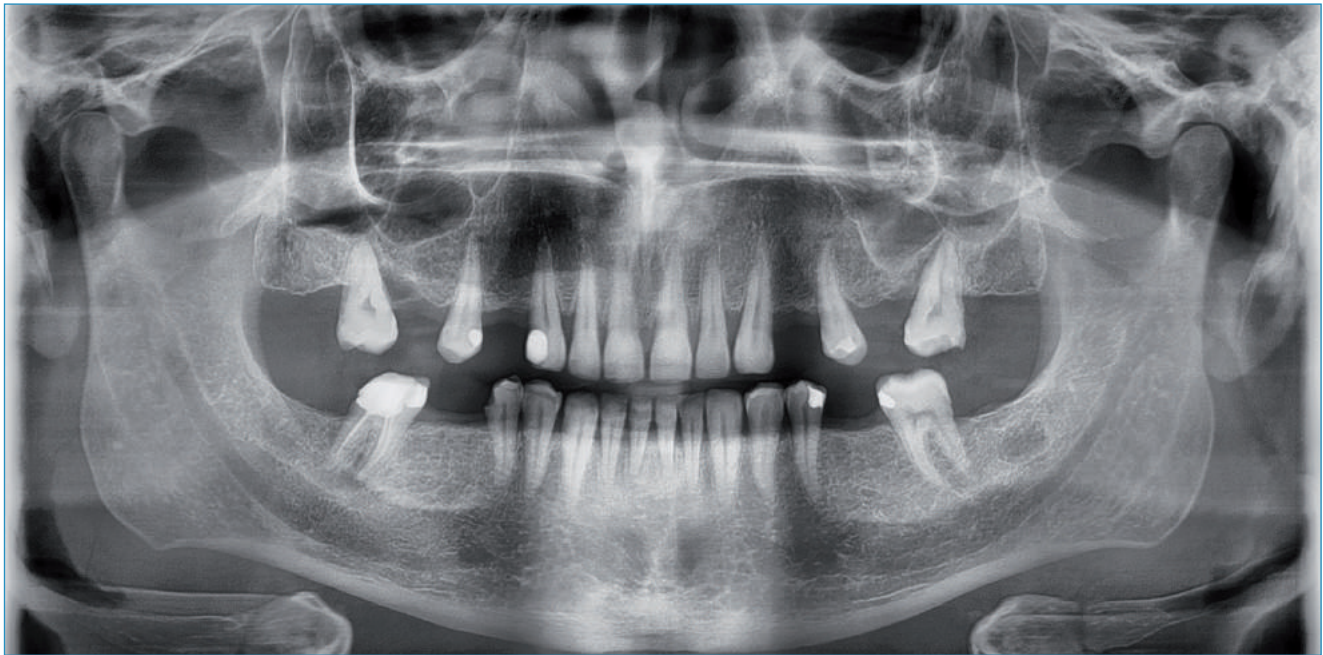


Fig. 2

beam computed tomography. As there was not enough bone height to place an implant in a standard way, it was decided to proceed with a traumatic sinus lift. The patient did not present any contraindication to or systemic disease that would contraindicate the procedure.

Surgical procedure

For the intervention of vertical increase of bone in the maxillary sinus, antibiotic pre-medication was prescribed: amoxicillin (500 mg, 1 tablet every 8 h for 7 days), starting 2 days before. It was also recommended to take ibuprofen (600 mg, 1 tablet) 1 h before surgery. Local anesthesia was administered by infiltration with articaine plus 1:100,000 epinephrine (Ultracain, 40 mg; Normon; 3 cartridges of 1.8 mL per cartridge).

A crestal incision was made in the edentulous area, followed by a vertical incision, mesial to the second premolar, surpassing the mucogingival line. A mucoperiosteal flap was raised to full thickness to visualize the lateral wall of the maxillary sinus. The extraction of the first molar was performed prior to access to the maxillary sinus.

The access to the maxillary sinus was performed using the lateral access technique. The window had dimensions of 10 × 8 mm, made first with a handpiece and tungsten carbide drill and then with a piezoelectric instrument (Piezomed, W&H). Then, to elevate the sinus membrane, angulated manual instruments were

used in direct contact with the bone (sinus membrane separators 718-EN2, MC-1 and MC-2, Bontempi).

The Valsalva maneuver to check whether the membrane had suffered any perforation was positive. We thus placed a small piece of membrane that covered it completely. Then we filled the whole sinus cavity with a bovine-derived xenograft (Bio-Oss, 0.25–1.00 mm granules; Geistlich Biomaterials). The total amount of xenograft used was 2.5 g. The lateral window was covered with a 13–25 mm resorbable collagen membrane (Bio-Gide, Geistlich Biomaterials). Seven simple sutures were performed with Supramid (5/0, circ., non-resorbable; Steinerberg), starting at the angles and continuing through the crestal and middle incisions. A periapical radiograph (**Fig. 3**) and a dental panoramic tomogram (**Fig. 4**) were taken at the end of the intervention.

The patient was provided with post-surgical instructions, both verbal and written. The recommendations included soft and cold food for the first several days, cold application in the surgical area, no smoking and avoiding brushing for the first several days, and use of a 0.12% chlorhexidine rinse (Perio•Aid, 0.2% chlorhexidine and 0.05% cetylpyridinium chloride; Dentaïd) for 1 min, 3 times a day for 10 days. The patient was told that he could make use of anti-inflammatory therapy for pain or swelling.

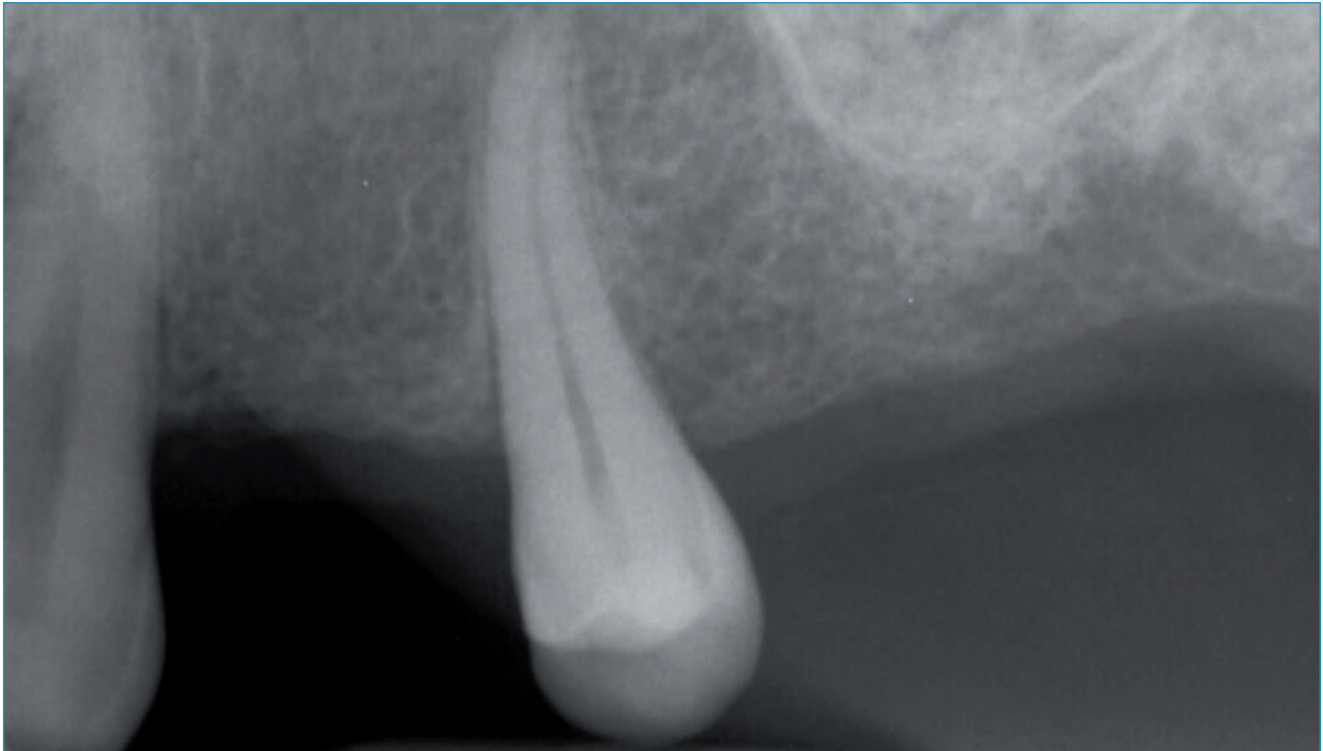


Fig. 3

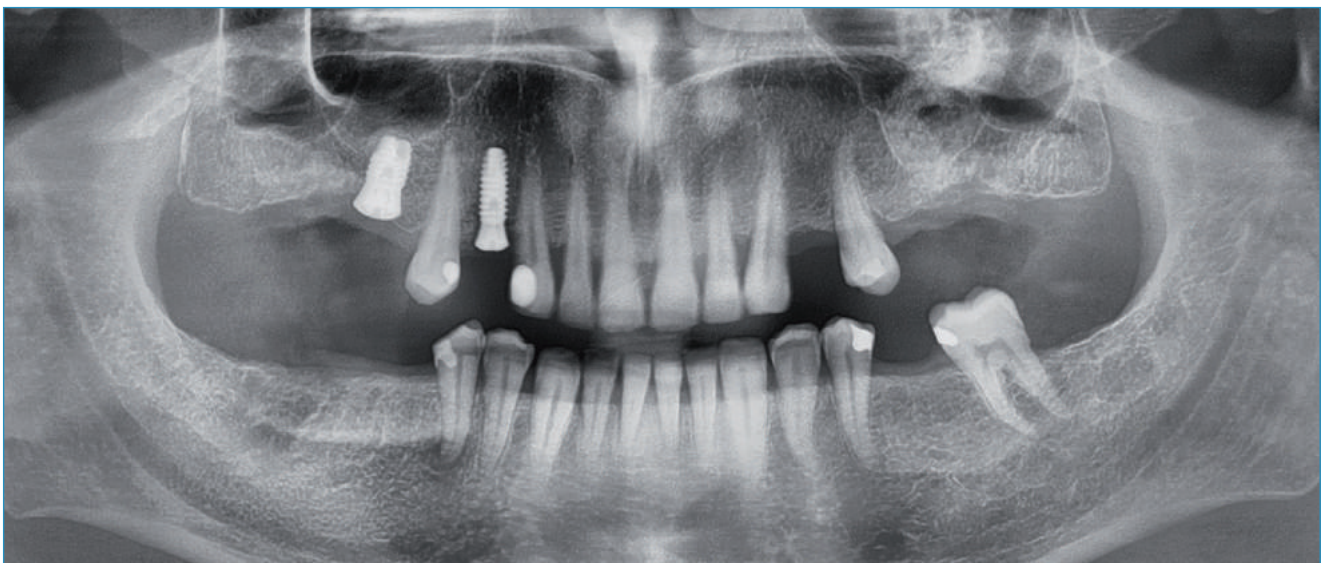


Fig. 4

Clinical management and resolution of orbital and periorbital emphysema

Onset and clinical aspect

On the same day of the surgery, 3 h later, the patient reported a large area of inflammation on the left side of the face that appeared immediately after 3 continuous sneezes (**Fig. 5**). The patient underwent a clinical examination of the affected area. He had no pain and his

sight was unaltered, although the inflammation limited the opening of the eyelid. The extrinsic musculature of the eye was not involved. A visit to an ophthalmological specialist was not considered necessary. A control dental panoramic tomogram was performed and it did not reveal any alteration in the bone elevation. The diagnosis of subcutaneous emphysema was explained to the patient. Amoxicillin, 875 mg, and clavulanic acid, 125 mg, 1 tablet every 8 h for 7 days, was prescribed.



Fig. 5a

Resolution

By the third day, the reduction of emphysema was already very noticeable, and the inflammation had decreased, disappearing completely after 7 days. The resolution of emphysema occurred without any other complication. The patient did not have an infection or pain.

Discussion

In the present clinical case, subcutaneous emphysema appeared after powerful sneezing of the patient after elevation of the maxillary sinus. The objective of the report of this case is to communicate the signs and symptoms of subcutaneous emphysema at the level of the periorbital area, as well as the favorable progress in a few days with good pharmacological management.

Many authors have recorded the complication of subcutaneous emphysema, especially after dental interventions. Most of them agree that the use of air-operated handpieces for dental extractions is the most frequent cause.^{4, 6, 11, 12} However, other reasons have also been described: preparation for and placement of crowns,¹³ endodontic treatment and retreatment, and the use of the dental laser.^{7, 14, 15}

It is important to make a differential diagnosis through comparison with other pathologies that produce an increase in volume, such as an allergic reaction or a hematoma. Therefore, a detailed clinical history and the correct palpation of the area to achieve a correct diagnosis is very important. The main manifestations that aided us in establishing a correct

differential diagnosis were swelling without redness and the crepitating palpation of the soft tissue.¹² Few authors have reported cases related to the eye and orbital tissue.^{10–16} Commonly, patients report no pain, but at worst a slight discomfort due to inflammation.

Air can enter the parapharyngeal and retropharyngeal spaces, where accumulation of air can lead to airway compromise, air embolism and soft-tissue infection. Pneumothorax, optic nerve damage and even death by air embolism has been reported.¹

Prophylactic antibiotics, meticulous observation of the respiratory tract and monitoring of gas extension are recommended.^{1,17} To prevent secondary infections, the administration of antibiotics is recommended. In this case, amoxicillin and clavulanic acid as prescribed was sufficient for resolution of the case.

Conclusion

The present case report has shown how subcutaneous emphysema can occur as a result of the sneezing of the patient after maxillary sinus augmentation. It was handled correctly with the use of antibiotics and follow-up. Subcutaneous emphysema did not affect the success of the vertical augmentation procedure.

Competing interests

The authors declare that they have no competing interests.

Legends

Fig. 1 – Preoperative periapical radiograph.

Fig. 2 – Preoperative dental panoramic tomogram.

Fig. 3 – Postoperative periapical radiograph.

Fig. 4 – Postoperative dental panoramic tomogram.

Fig. 5 – Clinical image of subcutaneous emphysema.

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Digital bone augmentation in posterior mandibles: A retrospective CBCT study and proposal of a 2-step bone augmentation protocol

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Abstract

Objective

The objective was to analyze bone resorption patterns in posterior mandibles and the dimensions of their corresponding digital bone grafts. This could allow the fabrication of bone grafts with standardized dimensions

that can be applied in the majority of clinical cases.

Materials and methods

Cone beam computed tomography scans ($n = 120$) were analyzed to evaluate the frequency of Cawood and Howell (C&H) classes. The most frequent class needing bone augmentation was virtually regenerated using specific software. Dimensions of the grafts were calculated.

Results

Class V was the most frequent atrophic class needing augmentation in posterior mandibles (20.4%). Severe atrophic stages were more frequent in females (adjusted P value = 0.001), in older people (adjusted P value = 0.31) and in the right mandible (adjusted P value = 0.03). After virtual regeneration of Class V cases ($n = 36$), 3 clusters based on the number of missing teeth were evident. The mean length of the grafts was 20 mm when 2 teeth were missing (reference), 23.9 mm in the case of 3 missing teeth ($P < 0.001$) and 29.6 mm for 4 missing teeth ($P < 0.001$). Height and width were comparable across the 3 clusters (P -values = 0.39–0.93). The mean graft volume was 1,469 mm³ in the case of 2 missing teeth (reference), 1,814 mm³ for 3 missing teeth ($P = 0.001$) and 2,177 mm³ for 4 missing teeth ($P < 0.001$). These volumes corresponded to those of soft-tissue expanders, suggesting the possibility of a 2-step augmentation protocol: soft-tissue expansion, followed by regeneration with pre-fabricated grafts of the corresponding volume.

Conclusion

Class V was the most frequent resorption pattern requiring augmentation in posterior mandibles. Virtual regeneration revealed 3 clusters of grafts, differing only in length based on the number of missing teeth. A 2-step augmentation protocol is proposed using

soft-tissue expanders and prefabricated grafts with corresponding volumes. This protocol might be more applicable in the right mandible, females and older patients.

Keywords

Mandible; alveolar bone grafting; bone graft; cone beam computed tomography; soft-tissue expansion.

Introduction

To ensure a successful dental implant therapy, the presence of adequate amounts of vertical and horizontal alveolar bone is fundamental.¹ Therefore, horizontal and/or vertical alveolar bone augmentation procedures are performed whenever the alveolar bone volume is inadequate.

Although horizontal and vertical bone augmentation procedures are both technique-sensitive, the latter is more challenging and several surgical techniques are applied, such as vertical guided bone regeneration, onlay grafting, inlay grafting and distraction osteogenesis.^{2,3} As is known, vertical bone augmentation is frequently associated with high rates of complications, such as soft-tissue dehiscence and subsequent exposure of bone grafts in the oral cavity.⁴ Consequently, soft-tissue expansion (STE) has been introduced, to enhance the quantity and quality of soft tissue prior to bone augmentation procedures, by using self-inflating soft-tissue expanders (for a review, see Asa'ad et al.⁵). STE facilitates passive closure of the flap, thus decreasing patient morbidity and improving regenerative outcomes.

With the introduction of solid freeform fabrication techniques, researchers became interested in developing custom-made bone grafts with complex architectures⁶ that conform better to more complex defects, thus increasing the predictability of regenerative outcomes, especially in complex defect areas and in posterior mandibles, as the rehabilitation of this edentulous area with dental implants is very challenging for clinicians in modern dental practice.⁷ Such systems utilize computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies to 3-D print a desired structure based on a CAD file that contains the

already determined graft dimensions.⁸ In a typical clinical case scenario, CAD models are produced based on images from computed tomography (CT) scans of a patient-specific bone defect to develop a custom-made synthetic graft to regenerate defects with complex geometry⁹ (for a review, see Asa'ad et al.¹⁰).

Recently in the literature, a case series focused on the concept of custom-made grafts and minimally invasive surgical procedures for alveolar bone regeneration using subtractive technologies, that is, milling of a commercially available block using CAD/CAM technologies.¹¹ Nonetheless, creating a customized bone graft for every clinical case could be of very high cost, mainly owing to the required armamentarium and setup. In this regard, providing standardized prefabricated synthetic bone grafts that can be applied in most clinical case scenarios with minimal chairside modifications might be a more cost-effective alternative. This concept was previously investigated by Metzger et al., who evaluated the topographical anatomy of the human orbital floor for the production of prefabricated implants on the basis of data obtained from conventional CT.¹²

Therefore, the aim of the present retrospective study was to analyze bone resorption patterns in right and left posterior mandibles and the corresponding digital bone grafts, in a single population, to evaluate whether the grafts could be grouped into distinct clusters. We also present a preliminary analysis of the severity of bone resorption and number of missing posterior teeth in relation to age, sex and mandibular side. We also propose a 2-step bone augmentation protocol, entailing STE, followed by placement of a prefabricated bone graft of the corresponding volume.

Materials and methods

CBCT scans and inclusion criteria

An entire database (a total of 300 cone beam computed tomography [CBCT] scans dated from 2011 to 2016) of a private dental practice in Como, Italy, was accessed during the period of April–June 2016. All the CBCT scans were generated by the same CBCT equipment (Planmeca ProMax 3D Max, Planmeca, Helsinki, Finland) with the following exposure settings: 90 kV and 8 mA or 10 mA for 12 – 15 seconds.

After all the scans were screened, only 120 scans met the inclusion criteria, and thus were selected for the final analysis. As a routine protocol, all the patients signed an informed consent form agreeing to the use of their data for scientific purposes. All patients were treated according to the principles contained in the Declaration of Helsinki of 1980 for biomedical research involving human subjects. Screening of scans and selection were performed by the same investigator (FA).

The final CBCT scans met the following inclusion criteria:

1. Scans had to be of patients of 35 years of age or older. The cutoff point for inclusion was set at 35 years of age based on the finding in the literature that peak bone density is reached by age 35,¹³ after which bone density/mass starts to decrease.
2. Scans had to be of patients without any reported systemic diseases that affect bone (e.g., osteoporosis), as verified from patients' records.
3. At least 1 side of the posterior mandible had to be either partially or fully edentulous.
4. The edentulous area had to have at least 2 consecutive posterior missing teeth, 1 of them a molar, as follows: (i) missing first and second molars (2 teeth); (ii) missing second premolar and first and second

molars (3 teeth); and (iii) missing first and second premolars and first and second molars (4 teeth).

5. Alveolar bone resorption had to be physiological after tooth loss/extraction and not related to any trauma or pathologies, as verified from patients' records.

The CBCT scan exclusion criteria were the following:

1. Patients who reported systemic diseases that would affect the alveolar bone, for example osteoporosis.
2. History of previous bone grafting procedures, as this variable affects bone morphology.
3. Sole presence of edentulous maxillary sextants, as the upper jaw was not the region of interest in this retrospective study. It must be noted that the posterior mandible was selected as the region of interest because its rehabilitation is considered the most challenging for clinicians in modern dental practice.⁷

For the final 120 scans, each included at least 1 side of the posterior mandible that met the inclusion criteria for analysis. Afterward, the contralateral mandibular side was assessed as well. If it met the inclusion criteria, it was also included in the final analysis, but if not, that segment was excluded. It must be noted that, in that case, the segment was excluded from the overall frequency analysis and not the scan. The contralateral

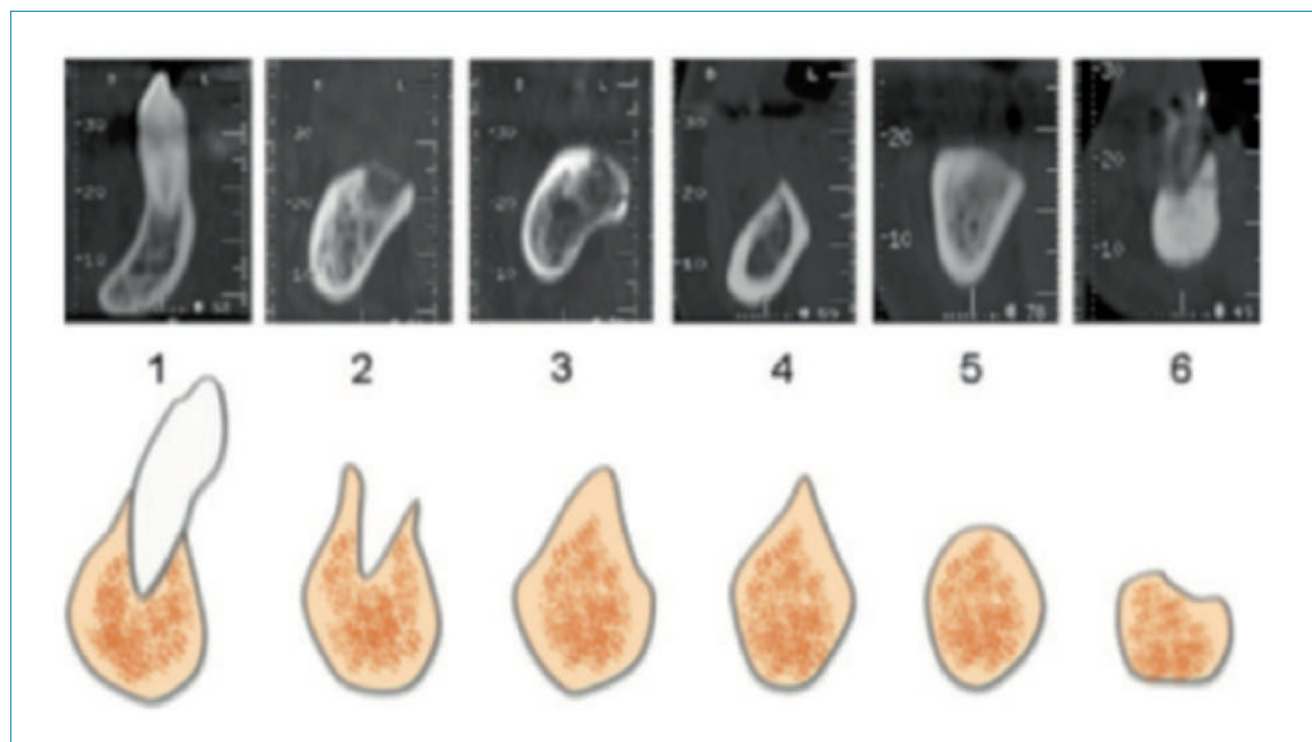


Fig. 1

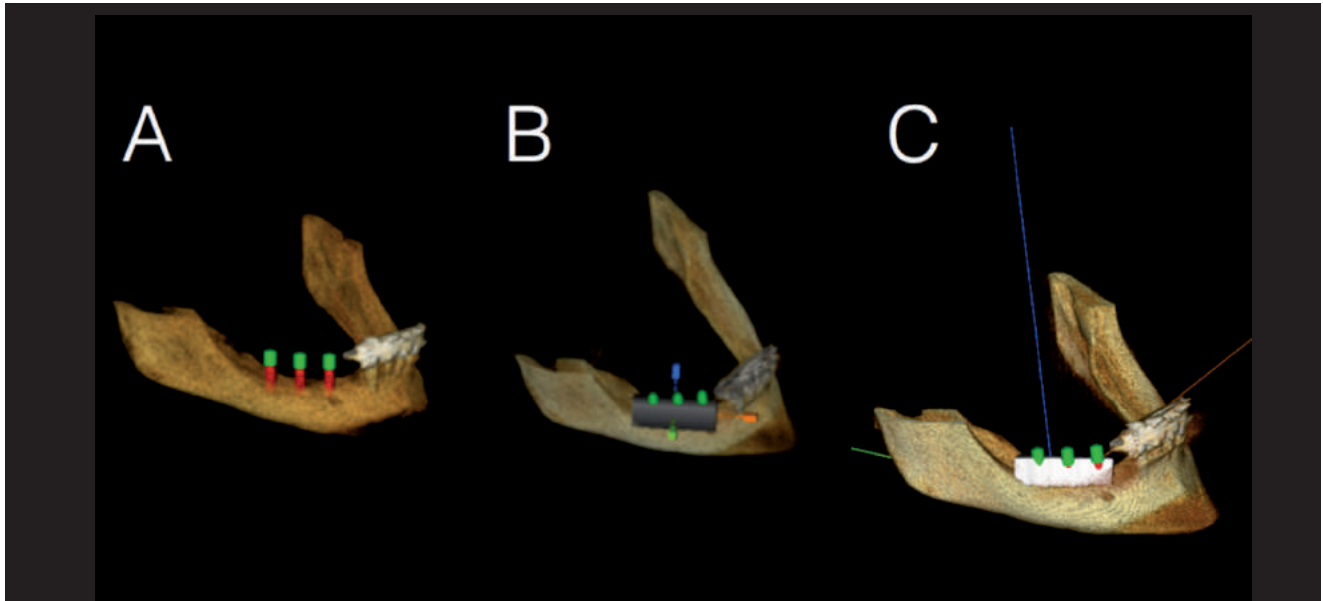


Fig. 2a

segment was eliminated from the final analysis if it had 1 of the following characteristics:

1. fully dentate arch (Cawood and Howell Class I);
2. nonconsecutive missing posterior teeth;
3. 1 missing posterior tooth;
4. 2 missing premolars;
5. bounded saddle areas consisting of a missing second premolar and missing first molar (first premolar and second molar were present); and
6. edentulous area already restored with dental implants.

Analysis of mandibular bone resorption patterns on CBCT scans

The pattern of the mandibular bone loss was assessed by the same examiner (FA), using the classification proposed by Cawood and Howell (C&H).¹⁴ This classification system is among the most widely used to categorize edentulous ridges.¹⁵ The ridge displays a specific shape during different phases of bone resorption that can be clearly identified on CBCT scans (**Fig. 1**).¹⁶ The C&H classification divides the posterior mandible into 6 groups as follows:

1. Class I: dentate;
2. Class II: immediately post-extraction;
3. Class III: well-rounded ridge form, adequate in height and width;
4. Class IV: knife-edge ridge form, adequate in height and inadequate in width;

5. Class V: flat ridge form, inadequate in height and width;

6. Class VI: depressed ridge form with some basal loss evident.

Frequency analysis of bone resorption patterns was done using DICOM files imported into OS3D 2.0 software (3DMed, L'Aquila, Italy). Frequency analysis of bone resorption pattern and number of missing teeth were compared for age, sex and mandibular side.

Virtual bone regeneration and digital bone grafts

Virtual regeneration with digital bone grafts was performed after the frequency analysis had been completed. This step was only done for the most frequent C&H class requiring bone augmentation (i.e., the most frequent class among Classes IV, V and VI).

By means of imaging software (OS3D 2.0), the digital data were processed to obtain a 3-D image of the bone loss, and a virtual graft was designed, simulating a real bone grafting procedure (**Fig. 2a**), as described by Jacotti et al.¹⁷ The software allowed the determination of the length, height and width of each graft. The software also verified the intimate adaptation between the virtual graft and the underlying bone surface. As a guide for the virtual bone regeneration procedure, the residual bone height above the mandibular canal was measured, and then the virtual graft height was determined by the ability to accommodate an implant of a standard height (10 mm) with a 2 mm

safety zone above the mandibular canal (**Fig. 2b**). Virtual graft width was determined by the ability to accommodate a 3.25 mm diameter dental implant. Virtual graft length was based on the number of missing consecutive posterior teeth. The 3-D planning software allowed for virtual dental implant placement, subsequent virtual bone regeneration and verification of the graft dimensions.

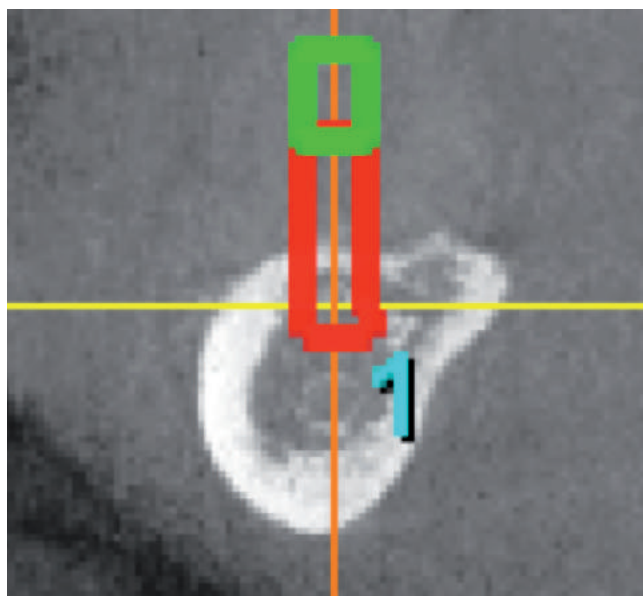


Fig. 2b

Statistical analysis

Random intercept univariate and multivariable linear regression models were fitted to evaluate the effect of sex, age and side on the C&H classes, the number of missing teeth and dimensions of virtual grafts (length, height, width and volume). Statistical analyses were performed using Stata 15 (StataCorp).

Results

A total of 120 patients contributed 120 CBCT scans and 240 posterior mandibular segments. A total of 59 contralateral mandibular segments were excluded from the final analysis (25 in the left mandible and 34 in the right mandible), and 181 left and right mandibular segments were analyzed overall (95 in the left mandible and 86 in the right mandible). The study participants were 47 males and 73 females with an age range between 37 and 92 years (mean age = 66.2 ± 11.2 years; **Table 1**).

Age group, years	Female, n (%)	Male, n (%)	Total, n (%)
< 65	23 (31.5)	21 (44.7)	44 (36.7)
≥ 65	50 (68.5)	26 (55.3)	76 (63.3)
Total	73 (100)	47 (100)	120 (100)

Table 1: Age and sex distribution of the study population.

The study sample was divided into 2 age groups: < 65 years old and ≥ 65 years old. Most of the study participants were of the second age category (63.3%). For the purpose of this study, the results will focus on C&H classes that require alveolar bone augmentation (i.e., Classes IV, V and VI).

Frequency of bone loss patterns in posterior mandibles in relation to sex, age and side (**Table 2**)

Females showed higher frequencies of Classes IV, V and VI in comparison with males (crude *P* value < 0.001; adjusted *P* value = 0.001). Class V was the most frequent class that requires augmentation in females (30.3%), while 5.6% of males had Class V in the posterior mandible. Class VI was the least frequent in relation to Classes IV and V in both sexes (6.4% in females; 2.8% in males).

Patients in the older age category showed higher frequencies of Classes IV, V and VI in comparison with younger patients (crude *P* value = 0.14; adjusted *P* value = 0.31). The most frequent class that requires augmentation was Class V in older (22.0%) and younger (17.5%) individuals.

In both mandibular sides, Class V was the most frequent class that requires augmentation in comparison with Classes IV and VI. However, Class V was more frequent in the right mandible than on the left side (23.3% and 17.9%, respectively; crude *P* value = 0.03; adjusted *P* value = 0.03).

Frequency of consecutively missing teeth in posterior mandibles in relation to sex, age and side (**Table 3**)

Most of the posterior mandibular segments in females had either 3 or 4 missing teeth (36.7%, 39.4%, respectively), while most of the mandibular segments in males showed 3 missing teeth (44.4%). Nonetheless,

Characteristics	Cawood & Howell classification					Total
	II	III	IV	V	VI	
Sex	n (%)	n (%)	n (%)	n (%)	n (%)	No. (%) of mandibular segments
Female	1 (0.9)	52 (47.7)	16 (14.7)	33 (30.3)	7 (6.4)	109 (100)
Male	1 (1.4)	60 (83.3)	5 (6.9)	4 (5.6)	2 (2.8)	72 (100)
Crude <i>P</i> value*						< 0.001
Adjusted <i>P</i> value**						0.001
Age						
< 65 years	0 (0.0)	45 (71.4)	7 (11.1)	11 (17.5)	0 (0.0)	63 (100)
≥ 65 years	2 (1.7)	67 (56.8)	14 (11.9)	26 (22.0)	9 (7.6)	118 (100)
Crude <i>P</i> value*						0.14
Adjusted <i>P</i> value**						0.31
Side						
Left	1 (1.0)	62 (65.3)	11 (11.6)	17 (17.9)	4 (4.2)	95 (100)
Right	1 (1.2)	50 (58.1)	10 (11.6)	20 (23.3)	5 (5.8)	86 (100)
Crude <i>P</i> value*						0.03
Adjusted <i>P</i> value**						0.03

* From random intercept univariate linear regression models.

** From random intercept multivariable linear regression models containing all three variables.

Table 2: Frequency of different bone loss patterns in posterior mandibles in relation to sex, age and side.

Characteristics	No. (%) of consecutively missing posterior teeth			Total
	2	3	4	
Sex				No. (%) of mandibular segments
Female	26 (23.9)	40 (36.7)	43 (39.4)	109 (100)
Male	24 (33.3)	32 (44.4)	16 (22.2)	72 (100)
Crude <i>P</i> value**				0.11
Adjusted <i>P</i> value**				0.21
Age				
< 65 years	23 (36.5)	26 (41.3)	14 (22.2)	63 (100)
≥ 65 years	27 (22.9)	46 (39.0)	45 (38.1)	118 (100)
Crude <i>P</i> value*				0.04
Adjusted <i>P</i> value**				0.06
Side				
Left	25 (26.3)	39 (41.1)	31 (32.6)	95 (100)
Right	25 (29.1)	33 (38.4)	28 (32.5)	86 (100)
Crude <i>P</i> value*				0.47
Adjusted <i>P</i> value**				0.47

* From random intercept univariate linear regression models.

** From multivariable linear regression models containing all three variables.

Table 3: Frequency of consecutively missing teeth in posterior mandibles in relation to sex, age and side.

Cawood & Howell classification	No. (%) of consecutively missing posterior teeth			Crude <i>P</i> value*	Adjusted <i>P</i> value**
	2	3	4		
II	0 (0)	1 (1.4)	1 (1.7)		
III	40 (80)	49 (68)	23 (39.0)		
IV	3 (6)	6 (8.3)	12 (20.3)		
V	7 (14)	12 (16.7)	18 (30.5)		
VI	0 (0)	4 (5.5)	5 (8.5)		
Total No. (%)	50 (100)	72 (100)	59 (100)	0.04	0.04

* From random intercept univariate linear regression models.

** From multivariable linear regression models containing all three variables.

Table 4: Number of consecutive missing teeth in posterior mandibles in relation to Cawood and Howell classification.

Virtual graft dimension	Two missing teeth (n = 6)	Three missing teeth (n = 13)	Four missing teeth (n = 17)
Length (mean ± SD), mm	20.0 ± 0.6 (reference)	23.9 ± 0.6 (<i>P</i> < 0.001)	29.6 ± 0.7 (<i>P</i> < 0.001)
Height (mean ± SD), mm	9.0 ± 0.9 (reference)	9.4 ± 1.2 (<i>P</i> = 0.39)	9.0 ± 0.8 (<i>P</i> = 0.93)
Width (mean ± SD), mm	8.2 ± 0.4 (reference)	8.1 ± 0.3 (<i>P</i> = 0.74)	8.2 ± 0.4 (<i>P</i> = 0.89)
Graft volume (mean ± SD), mm³	1,469 ± 152 (reference)	1,814 ± 248 (<i>P</i> = 0.001)	2,177 ± 224 (<i>P</i> < 0.001)

* *P* values from random intercept linear regression models adjusted for sex, age and side.

Table 5: Height, width and length of virtual grafts of Cawood and Howell Class V.

sex did not seem to influence the number of consecutive missing teeth in the posterior mandible (crude *P* value = 0.11; adjusted *P* value = 0.21).

Posterior mandibles in patients of ≥ 65 years of age showed mostly 3 or 4 missing teeth (39.0% and 38.1%, respectively), while the posterior segments in the younger age group showed mostly 2 or 3 missing teeth (36.5% and 41.3%, respectively). These results show that the number of missing teeth might be influenced by age (0.3 more missing teeth on average among older patients; crude *P* value = 0.04; *P* = 0.06, adjusted for sex and side).

Both right and left posterior mandibles had comparable frequencies of the number of missing teeth. Three missing teeth were the most frequent for both sides, while 2 missing teeth were the least frequent (crude *P* value = 0.47; adjusted *P* value = 0.47).

Frequency of consecutively missing teeth in posterior mandibles in relation to bone loss patterns (Table 4)

Posterior mandibles that showed Classes IV, V and VI had mostly 4 missing teeth. In Classes IV and V, the frequency of 2 and 3 missing teeth was almost comparable. None of the mandibles with Class VI had

2 missing teeth (crude P value = 0.04; adjusted P value = 0.04).

Dimensions of digital bone grafts for mandibular segments with Class V (Table 5)

As Class V was the most frequent among classes that require bone augmentation (i.e., the most frequent among Classes IV, V and VI), virtual bone regeneration of Class V mandibular segments was performed through digital bone grafts, using specific software. Among the 181 analyzed mandibular segments, 37 segments were of Class V. However, virtual bone regeneration was only performed for 36 segments, as 1 segment was excluded owing to technical difficulties encountered with the provided CBCT scan of the patient, which did not allow for the procedure to be successfully performed. Regarding the length of the virtual graft, the mean was 20 ± 0.6 mm when 2 teeth were missing. When 3 teeth were missing, the mean length was 23.9 ± 0.6 mm. In cases of both premolars and both molars missing, the mean length was 29.6 ± 0.7 mm. Mean length was different based on the number of missing teeth ($P < 0.001$).

As for the width of the virtual graft, it was almost comparable when 2 (8.2 ± 0.4), 3 (8.1 ± 0.3) or 4 teeth (8.2 ± 0.4) were missing ($P > 0.05$). Regarding the height of the virtual graft, this dimension was also comparable when 2 (9.0 ± 0.9), 3 (9.4 ± 1.2) or 4 teeth (9.0 ± 0.8) were missing ($P > 0.05$).

Discussion

To the best of the authors' knowledge, this is the first retrospective study to analyze the frequency of C&H classes on CBCT scans and virtually regenerate the most frequent atrophic class that requires bone augmentation. As findings in the literature are inconsistent regarding the severity of bone resorption in relation to sex, the frequency of C&H classes between males and females was compared in the present study as well. The C&H classification¹⁴ was applied in this retrospective analysis because it is among the most used to categorize edentulous ridges¹⁵ and the different shapes of a ridge of each class can be easily identified on CBCT scans.¹⁶ To date, there is only 1 study that assessed the frequency of C&H atrophic stages. However, this investigation was in a historic nation and only evalu-

ated the association between age and frequency/severity of atrophy.¹⁸ After the frequency analysis of bone resorption patterns, dimensions of digital grafts were assessed as well, to determine whether the virtual grafts could be grouped into distinct clusters, which could allow the fabrication of bone grafts of standardized dimensions that could be applied in the majority of clinical cases.

The findings of the present study suggest that females show higher frequencies of severe atrophic stages in comparison with males; thus, sex tends to influence bone resorption. These results are consistent with what has been previously reported in the literature. Solar et al. suggested that female sex was an independent risk factor for more severe bone resorption in the mandible.¹⁹ In another study, female sex was indicated as a risk factor for greater bone resorption in the posterior mandible;²⁰ however, this study focused on patients wearing conventional dentures and implant overdentures. Interestingly, the tendency of females to show more bone resorption than their male counterparts might be due to females having deeper resorption lacunae.²¹ In a different investigation, more severe resorption in females was due to lower bone mineral content of the mandible in young dentate women when compared with young dentate men.²² As is known, the less highly mineralized a substrate is, the more easily it can resorb.²³ In contrast, Winter et al. reported more bone loss in the posterior mandible in males, due to greater biting force.²⁴

In the present retrospective analysis, C&H Class V was the most frequent among the 3 atrophic classes that require bone augmentation (i.e., Classes IV, V and VI) among all study participants, while Class VI was the least frequent. In a retrospective analysis of a historic nation, atrophy stages V and VI were both the most frequent among older age groups.¹⁸ Since the population of the present retrospective analysis is not historic, the negligible frequency of class VI frequency can be justified by the fact that patients do seek dental treatment at some point before bone resorption progresses to basal bone. As expected, the older age group (≥ 65 years) in the current retrospective analysis showed more severe C&H classes of resorption in comparison with the younger age group (< 65 years). Similarly, in a historic nation, the severity of bone resorption was associated with the individual's age.¹⁸

Moreover, the results of the present study revealed that the number of missing teeth is influenced by age.

As Class V was the most frequent among the atrophic classes that require bone augmentation, all Class V cases were virtually regenerated with digital bone grafts. This procedure was guided by virtual implant placement, to ensure that the dimensions of the virtual grafts were correct. Based on these dimensions, 3 clusters were notable—graft length of 21, 25 and 30 mm—based on the number of missing teeth. In these clusters, graft width and height were almost comparable (8 mm and 9 mm, respectively). Therefore, it might be logical to propose that using prefabricated bone grafts in most clinical case scenarios could be practical and applicable. Utilization of prefabricated bone grafts could be more applicable in right mandibles in females and older patients, based on the results of the current study.

Whether the prefabricated graft may need minimal or major modification for adaptation is to be confirmed in a future study, by calculating and comparing the adaptation ratio of both the virtual and actual grafts. It has been suggested that shaping and modification of a chairside graft highly increase the risk of contamination and subsequent infection, which could compromise the outcomes of the bone regeneration procedure.¹⁷

In the present study, the virtual bone augmentation procedure was guided by virtual placement of dental implants. One might argue that dental implants shorter than 10 mm can be used in posterior mandibles with predictable outcomes. Indeed, short dental implants are a valid option for restoring posterior mandibular

regions, as is vertical bone augmentation combined with implants of standard length (i.e., 10 mm);^{25, 26} however, since the aim of the present study was to analyze the virtual graft dimensions, the second treatment option was adopted (i.e., vertical bone augmentation), and a virtual implant of standard length was used to guide the virtual bone augmentation procedure. Narrow implants (i.e., 3.25 mm) were used, as their successful application in the posterior mandible has been previously reported as a minimally invasive alternative to horizontal bone augmentation.²⁷ Therefore, placing a virtual implant with a narrow diameter was done in order to decrease the horizontal bulkiness of the graft.

Although the current study suggests 3 different volumes of bone grafts based on the number of missing teeth, this aspect represents just 1 component of the entire clinical paradigm. In fact, case management is influenced by various factors that must be taken into consideration: the patient's socio-economic status; application of the short dental arch concept; length, diameter and number of dental implants; and utilization of a removable prosthesis instead of implant therapy. Although one might think that the bone graft volumes generated might be insufficient at the time of implant surgery, as graft resorption during osseous healing is still not predictable, it must be noted that prefabricated grafts could be made of biomaterials that have a degradation rate in concordance with the remodeling processes of the target tissue.¹⁰ In this context, a 2-step regenerative protocol can be implemented: pre-augmentation STE technique (**Fig. 3**),^{5, 28} followed by regeneration with prefabricated grafts. In this approach, a suitable self-inflating soft-tissue expander and its

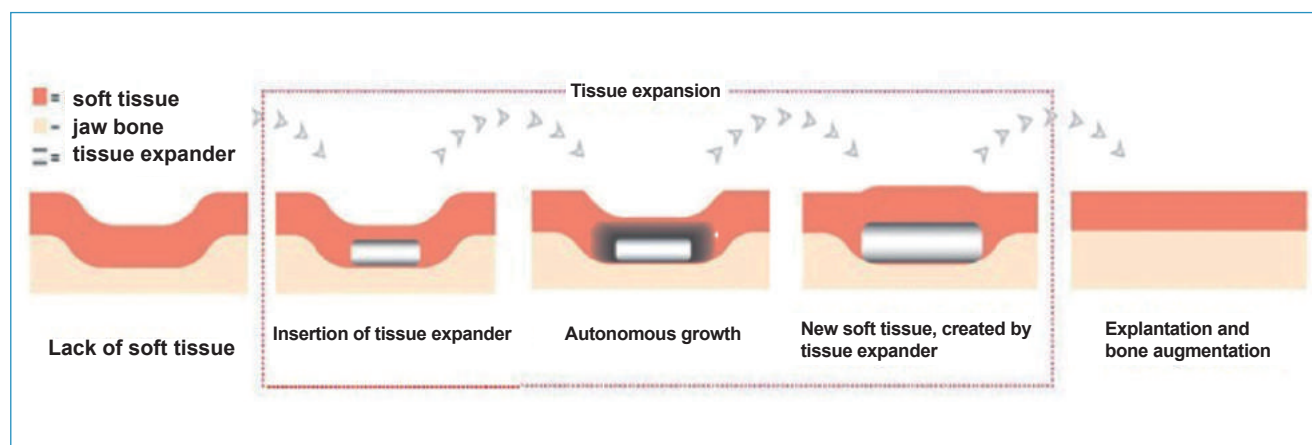


Fig. 3

corresponding bone graft volume are chosen for each individual patient after thorough treatment planning of the case. The virtual graft volumes obtained in this retrospective study appear to correlate to the available soft-tissue expander volumes. For example, the mean virtual graft volume obtained when 4 posterior mandibular teeth were missing was 2,177 mm³. This corresponds to the 2.1 mL (2,100 mm³) final-volume expander. Therefore, utilizing an expander of this volume and the corresponding bone graft volume could be applicable in a Class V posterior mandible with 4 missing teeth. Likewise, the mean virtual graft volume when 3 teeth were missing was 1,814 mm³. The matching soft-tissue expander volume in this case would be either a 1.3 or a 2.1 mL final-volume expander. In the case of 2 missing teeth, the mean virtual graft volume was 1,469 mm³, suggesting that a 1.3 mL final-volume expander would be the most suitable in this clinical situation. However, future studies focused on soft-tissue expanders and their corresponding graft volumes are needed to confirm these preliminary findings and the benchmark values generated.

The results of this retrospective study should be interpreted with caution, as it has certain limitations. The inclusion criteria for the analyzed CBCT scans, obtained from the same dental practice, were developed for the purposes of utilizing prefabricated grafts, and thus, our findings are not generalizable. As this was a pilot investigation, only areas with a free-end saddle were evaluated, thus excluding bounded saddle areas consisting of a missing second premolar and missing first molar. Therefore, further studies, also with larger sample sizes, are still needed.

Conclusion

Class V atrophy was the most common among the C&H classes that require bone augmentation in the right mandible and among females and the older age group. Virtual regeneration of Class V defects suggested the possibility of 3 clusters of bone grafts, depending on the number of missing teeth. Further studies are needed to evaluate the adaptation ratio between the virtual and actual grafts to conclude whether the grafts need minor or major shaping and modification at chair-side before clinical application. Moreover, the current findings might help in developing a 2-step bone aug-

mentation protocol: pre-augmentation STE technique, followed by regeneration with prefabricated grafts. This protocol could facilitate bone augmentation procedures for clinicians and decrease patient morbidity, especially in the case of complex defects.

Acknowledgments

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Competing interests

The authors report no conflict of interest related to this study.

Legends

Fig. 1 – Appearance of different Cawood and Howell classes on CBCT scans “Courtesy of Saavedra-Abril J A, Balhen-Martin C, Zaragoza-Velasco K, et al. Dental multisession CT for the placement of oral implants: Technique and applications. Radiographics 2010;30:1975-1991” Reference 16. Figure is used by permission of RSNA (Radiological Society of North America).

Fig. 2a – Creation and positioning of virtual bone grafts using OS3D 2.0 software.

Fig. 2b – Virtual placement of dental implants using the software as guidance for virtual graft reconstruction of a Cawood and Howell Class V.

Fig. 3 – Pre-augmentation soft-tissue expansion technique (with permission of osmed, Ilmenau, Germany).

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Autotransplantation: Salvaging an odontoma-associated unerupted anterior tooth

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Abstract

Background

Autogenous tooth transplantation is a viable option in cases involving impacted teeth, congenitally missing teeth, tooth loss and ectopic teeth. The method is considered superior to a removable prosthesis, as it maintains proprioception and alveolar bone height. Compared with dental implants, autotransplantation can provide faster healing, function and esthetic improvement at minimal cost.

Case presentation

The first case involved a patient referred for an unerupted maxillary left central incisor associated with

odontomas. The odontomas were surgically removed and the impacted maxillary left central incisor placed into occlusion and held in situ using a composite splint. Root canal therapy was carried out in a single visit at her subsequent appointment. The composite splint was retained for 6 weeks.

The second case involved a patient referred owing to eruption of multiple small tooth-like structures at her maxillary right central incisor. A diagnosis of an impacted maxillary right central incisor secondary to erupted odontomas was made. The procedure of autotransplantation was carried out in stages, first removing the odontomas and clearing the recipient site of infection, followed by surgical repositioning of the impacted maxillary central incisor. Its root canal therapy was completed in a single visit later, and the tooth continued to be retained by a composite splint for the duration of 6 weeks.

Conclusion

Autotransplantation has advantages and disadvantages in the case of tooth impaction. The treatment must be considered individually, and the patient must be fully informed of the procedure involved.

Keywords

Tooth autotransplantation; impacted tooth; odontoma.

Introduction

Autotransplantation is a procedure that entails relocating the patient's own teeth from 1 site in the oral cavity to another. Ectopic teeth, tooth loss or congenitally missing teeth are among the clinical situations for which autotransplantation is indicated.¹ Unlike a removable prosthesis, an autotransplanted tooth provides proprioceptive properties during function and allows maintenance of the alveolar bone mass. Therefore, it not only serves to fill the empty ridge for esthetic



Fig. 1

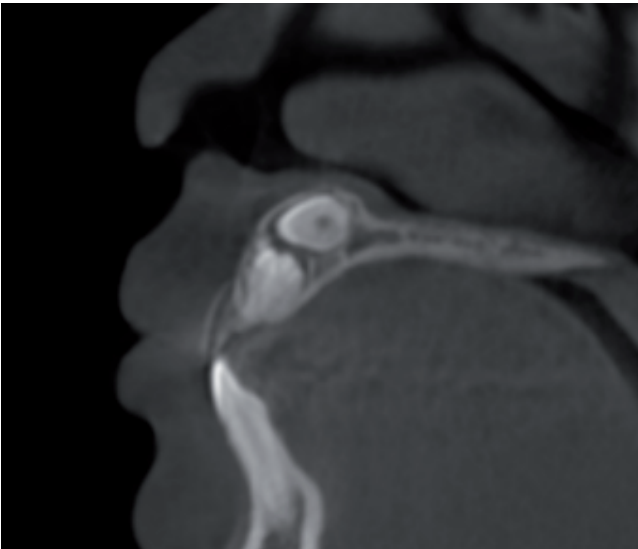


Fig. 2

purposes, but restores a normal, functional dentition at a relatively lower treatment cost compared with implants, a fixed prosthesis or orthodontic closure.

Survival of the transplanted tooth is influenced by the preoperative, peroperative and postoperative conditions. Preoperatively, the donor tooth must be evaluated regarding its suitability for transplantation elsewhere on the ridge. This includes the morphology of its crown and roots, presence of associated pathologies and state of the recipient site. Cautious handling of the tooth during its transfer from its original site to the new bed, the proper surgical technique and good immobilization following that also contribute to the good prognosis of the transplanted tooth. The patient's commitment to maintaining excellent oral hygiene and compliance with the postoperative instructions are no doubt indispensable.²

Odontoma is the most common odontogenic tumor, and its presence may be associated with delayed eruption or total impaction of dentition. Although it can be either complex or compound in nature, the type of odontoma does not have any significant clinical effect. Usually, odontomas can be found in the maxillary anterior region, affecting development and eruption of maxillary central incisors and canines. The diagnosis of odontoma is often a coincidental radiographic finding, resulting from investigation of delayed eruption or absence of a tooth in the arch.

In this article, we highlight 2 cases of autotransplantation of impacted maxillary central incisors after removal of embedded and erupted odontomas, respectively.

Case presentation

Case 1

A 17-year-old female patient was referred to our oral maxillofacial surgery unit for eruption failure of the maxillary left central incisor. She had no contributory medical history that may have been associated with this condition. The patient reported that her primary maxillary left central incisor had exfoliated at the age of 8 years and following that no permanent tooth had come into occlusion. On oral examination, there was no palpable swelling or protuberance that might indicate the presence of the maxillary left central incisor (**Fig. 1**). A cone beam computed tomography (CBCT) scan was taken, and it revealed a cluster of multiple radiopaque tooth-like structures in the maxillary left anterior region. Adjacent to these lay the impacted maxillary left central incisor, in a horizontal orientation close to the nasal floor (**Fig. 2**). A diagnosis of a horizontal impacted maxillary left incisor secondary to odontomas was made. The patient was informed about the treatment options available and she opted for the impacted central incisor to be salvaged.

Under general anesthesia, an intrasulcular incision was made from the maxillary right central incisor to the maxillary left lateral incisor, with releasing incisions made on both ends. A full-thickness flap was raised. Buccal bone was removed to expose the odontoma cluster and a total of 13 denticles were then removed (**Fig. 3**). Just above the cluster of odontomas, the im-

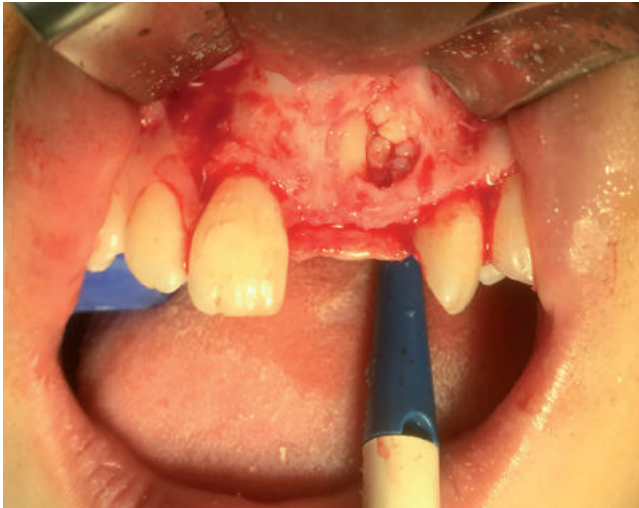


Fig. 3



Fig. 6



Fig. 4



Fig. 7



Fig. 5



Fig. 8

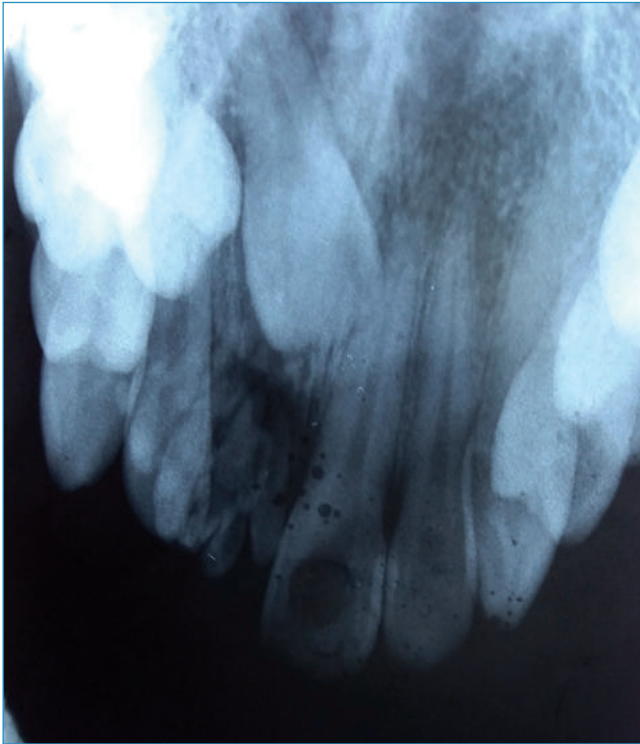


Fig. 9



Fig. 10

pacted central incisor was identified. Care was taken to remove this tooth as atraumatically as possible to avoid fracture, and the patient's own blood was used to preserve it while the recipient bed was prepared (**Fig. 4**). The tooth was then transplanted into position with the best possible occlusion using composite and stainless-steel wire (**Fig. 5**). Four weeks after the surgery, root canal therapy was completed in a single visit, and 2 weeks after that, the splint was removed, leaving the tooth with normal mobility and occlusal function.

Six months after surgery, follow-up examination showed a satisfactory appearance (**Fig. 6**), normal tooth mobility and no discoloration of the transplanted tooth. The dental panoramic tomogram showed good bony healing around the cervical and middle thirds of the root (**Fig. 7**).

Case 2

A 19-year-old female patient was referred to our unit owing to the presence of multiple small teeth occupying her maxillary right central incisor region. She reported that these had erupted after her primary teeth had exfoliated at the age of 7 years. On examination, multiple tooth-like structures were found to be occupying the space between the right lateral incisor and left central

incisor (**Fig. 8**). A slight palpable bulge could be felt at the vestibule above the maxillary right central incisor region. A maxillary occlusal radiograph revealed a cluster of radiopaque tooth-like structures at the alveolar ridge and an impacted maxillary central incisor lying close by (**Fig. 9**). A diagnosis of an impacted maxillary right central incisor secondary to erupted odontomas was made. The possibility of autotransplantation was discussed with the patient and she keenly expressed her full commitment.

Extraction of all the erupted odontomas was performed under local anesthesia and the site was allowed to heal before the transplantation procedure was carried out. This was to clear the future transplantation site of any infection, as it was noted that there was a labial sinus that had highly likely arisen from 1 of the odontoma. The neighboring teeth were all vital without pocketing.

After 2 weeks, local anesthesia was administered, and an incision was made from the maxillary right canine to the maxillary left lateral incisor, with bilateral releasing incisions. A full-thickness flap was raised to expose any remaining odontoma. A single odontoma was revealed and removed. The impacted central incisor was exposed, meticulously luxated and kept in



Fig. 11



Fig. 12

the patient's own blood. Slight guttering was done on the alveolar bone to accommodate the central incisor (**Fig. 10**). The tooth was splinted into position and kept in the best possible occlusion with composite and stainless-steel wire (**Fig. 11**). Root canal therapy was done 4 weeks after the surgery and the splint removed 2 weeks thereafter.

Follow-up examination after 6 months showed a satisfactory appearance, normal tooth mobility and no discoloration of the transplanted tooth (**Fig. 12**). A periapical radiograph was taken and revealed good bony healing around the transplanted tooth (**Fig. 13**).

Discussion

Tooth relocation involving a site previously occupied by odontomas is not common practice, as it is not part of any identified indication for autotransplantation.² Certain cases of an impacted tooth associated with the presence of odontoma can be managed through spontaneous eruption or orthodontics-assisted eruption after removal of the physical obstructions. According to Ashkenazi et al., spontaneous eruption of an impacted tooth correlates with several conditions, such as the distance of the impacted tooth's apex from its proper position, impaction depth, angle of impaction relative



Fig. 13

to the midline, and timing of surgery relative to the expected eruption.³ In a retrospective study of unerupted maxillary incisors associated with supernumerary teeth by Mason et al., three-quarters of the immature teeth erupted spontaneously, while half of the mature teeth needed a second surgery to bring them into occlusion.⁴ Their findings support the theory that unerupted incisors with closed apices are associated with slow eruptive movement.⁵ Both of our patients were not suitable candidates for such treatment methods. Their impacted teeth had fully developed roots and large angles of impaction. Spontaneous eruption was very unlikely. Surgical exposure and orthodontic alignment too were not options owing to the teeth's unfavorable positions and depths of impaction.

In our patients, tooth autotransplantation had been offered as a treatment choice after considering several factors. First of all, radiographic investigation had revealed that the impacted tooth was not associated with a suspicious cystic or other pathological lesion, apart from the odontomas hindering its normal eruption. Morphologically, both of the impacted teeth had

normal crown sizes, and even though their roots were slightly shorter than those of the erupted counterparts, they were nondilacerated. Regarding availability of space, there was ample room for transplantation of the impacted tooth in case 1. The space had been maintained by provision of a maxillary partial denture by the patient's previous dentist and partly by the presence of the odontomas underneath. In case 2, the space for transplantation was slightly limited by the palatally erupted lateral incisor. The oral hygiene of both patients was good, and they were eager to have their impacted teeth brought into position and functional in normal occlusion.

Among the drawbacks of tooth autotransplantation that should be highlighted to patients before embarking on this procedure are the risks of ankylosis of the transplanted tooth, inflammatory resorption, tooth discoloration and possible loss in subsequent years.

The survival rates of autotransplanted teeth vary. Overall, teeth with immature root formation have higher survival and success rates compared with mature teeth.⁶ One study has even shown survival rates of autotransplanted teeth with complete root formation to be as high as 98% for 1 year and 90% for 5 years.⁷ This finding indicates that, even with complete root formation, autotransplantation can be a viable, relatively economical option for replacement of missing teeth.

Autotransplantation is seen as a technique-sensitive procedure for which maintenance of the periodontal ligament is very crucial. Continued vitality of this structure is the most significant determinant for survival of the transplanted tooth.⁶ To allow proper differentiation of periodontal ligament cells, it is essential to minimize inflammation surrounding the transplanted tooth. Sources of potential inflammation must be eliminated, such as through tight suturing of gingival cuff to prevent bacterial ingress⁸ and good timing of root canal therapy (RCT).⁶ It has been suggested that RCT of fully developed donor teeth should be started 2 weeks after transplantation, to keep trauma as minimal as possible during the initial healing phase of reattachment of the periodontal ligament. Further delay will increase the risk of pulpal infection, which in turn will increase the possibility of secondary inflammatory resorption.⁶ RCT in both our patients was started after 4 weeks of transplantation while the tooth

was still in a splinted position. The rationale of this is to allow adequate reattachment of the periodontal ligament and more bone deposition before subjecting the tooth to the motion of the cleaning and shaping of RCT. We decided to complete the RCT in a single visit, as the tooth was asymptomatic in each case. There is insufficient evidence to show whether multiple-visit RCT is superior to single-visit RCT or vice versa.⁹

Other than good alveolar bone support and adequate keratinized tissue, the recipient site must be free from acute and chronic infections.¹⁰ Therefore, apart from an aseptic technique, a systemic antibiotic was given to increase the prognosis of the relocated tooth. Without its use, the occurrence of root resorption has been reported to be 1.4 times higher.⁷ The results clearly demonstrate the clinical benefit of giving systemic antibiotics to increase the survival of autotransplanted teeth.⁷ For an antibiotic regimen, we adopted the guideline for management of an avulsed tooth, which recommends the use of tetracycline or amoxicillin.¹¹ We prescribed to our patients oral amoxicillin (500 mg) 3 times daily for 1 week duration.

Surgical removal of impacted teeth and intraosseous odontomas might necessitate bone grafting to fill up the bone cavity created. The required material may be taken from the patient as an autogenous graft or processed bone granules may be utilized. However, if the cavity is small and the circumference of the bone surrounding the transplanted tooth is good enough, bone grafting may not be needed at all. A scaffold to promote blood clotting and provide a growth factor reservoir can be achieved by oxidized cellulose polymer, which is readily available in the clinic.

The first case report of combined odontoma removal and autotransplantation was by Hwang et al.¹² After 14 months of follow-up, the case had shown a satisfactory result in terms of appearance and periodontal status.¹² Both of our cases resemble theirs, with immediate replantation of unerupted maxillary anterior teeth associated with odontomas in teenage patients. The usefulness of this tooth relocation procedure compared with conventional prosthetic restoration such as a dental implant is that the tooth is biological, and with good preservation of the periodontal ligament, physiological stimulation will maintain the alveolar bone height and width. It is also cost-effective, does not

entail sacrifice of adjacent tooth structure like bridge-work preparation does and is more comfortable, as it can be left in situ, unlike removable partial dentures. The transplanted tooth is hoped to be able to serve its function and esthetic purpose for as long as possible, at least throughout the patient's growing years. The option of osseointegrated implants may present later, when patients have reached adulthood and their jaw growth is stabilized.

Conclusion

Immediate autotransplantation using the salvaged impacted tooth can be considered by surgeons in the management of edentulism, especially in the maxillary anterior regions of growing adolescent patients. The technique is relatively quick and inexpensive for addressing esthetic and functional demands. Nevertheless, it is important for the patient to fully understand the procedure involved, as well as the advantages and limitations of this method of tooth replacement.

Acknowledgments

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Competing interests

The authors declare that they have no competing interests.

Legends

Fig. 1 – Clinical preoperative photograph of the patient with absence of the permanent maxillary left central incisor.

Fig. 2 – Sagittal view of the CBCT scan showing the presence of an impacted tooth in relation to the odontoma.

Fig. 3 – Intraoperative photograph of the odontomas.

Fig. 4 – Prepared recipient site.

Fig. 5 – Placement and splinting of the transplanted tooth.

Fig. 6 – Six-month postoperative photograph showing no discoloration of the transplanted tooth.

Fig. 7 – Radiograph showing good bone healing without signs of root ankylosis or root resorption.

Fig. 8 – Preoperative photograph showing erupted odontomas with sinus opening.

Fig. 9 – Occlusal radiograph showing the impacted tooth.

Fig. 10 – Intraoperative photograph of the cavity after removal of the impacted tooth.

Fig. 11 – Transplantation of the impacted tooth.

Fig. 12 – Six-month postoperative photograph showing no discoloration of the transplanted tooth.

Fig. 13 – Radiograph showing good bone healing without signs of root ankylosis or root resorption.

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Evaluation of the muscular activity and myodynamic balance in children with physiological dental occlusion

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Abstract

Objective

The objective was to evaluate the homogeneous myoelectric activity of the maxillofacial area and to identify the myodynamic musculature balance in children of different ages with a physiological dental occlusion.

Materials and methods

Sixty children, 30 aged 7–9 years and 30 aged 10–12 years, with an Angle Class I relationship and

who had no clinical symptoms, temporomandibular disorders, cross bite, deep bite or open bite, and were not bruxers underwent a surface electromyographic examination. The bioelectric potentials of the left and right temporalis, masseter, suprahyoid and sternocleidomastoid muscles were evaluated in maximum clenching.

Results

The electroactivity of the muscles measured with root mean square and average rectified value did not present statistically significant differences between the groups, even though different values in relation to age were found. Among the 7- to 9-year-olds, the root mean square index in maximum clenching for the masticatory muscles was $256.5 \pm 9.0 \mu\text{V}$ on the right and $254.0 \pm 7.3 \mu\text{V}$ on the left and for the suprahyoid muscles was $27.3 \pm 3.2 \mu\text{V}$ and $31.6 \pm 3.7 \mu\text{V}$, respectively. In the group of 10- to 12-year-olds, the values were $374.8 \pm 15.5 \mu\text{V}$ and $354.0 \pm 16.4 \mu\text{V}$, respectively, for the masticatory muscles and $23.4 \pm 1.9 \mu\text{V}$ and $22.4 \pm 2.1 \mu\text{V}$, respectively, for the suprahyoid muscles.

Conclusion

Any deviation from the values reported in the present study suggests the presence of occlusal and/or postural problems.

Keywords

Clinical research protocol; clinical trial; randomized controlled trial; dental occlusion; stomatognathic system; masticatory system; orthodontics

Introduction

Surface electromyography (sEMG) is an objective information tool of the functional state of the neuromuscular system of the masticatory apparatus.¹ Technological progress has made it possible to extend the scope of measurement tools in stomatology; the development

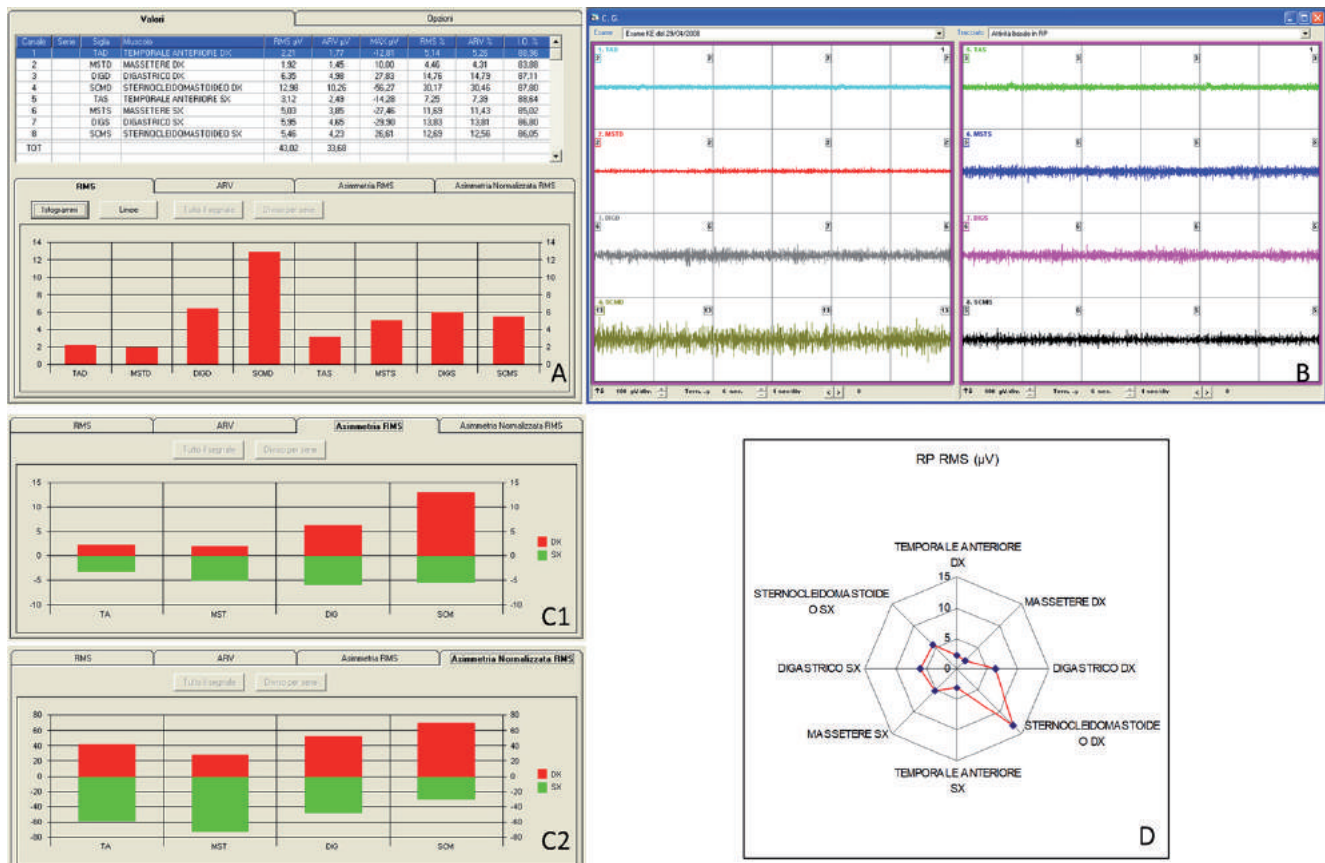


Fig. 1

of digital techniques has allowed the creation of surface electromyographs that combine analog equipment and computers. The latter receives the signals detected by the surface electromyograph in digital and then processes and displays them in tables, histograms and other graphs (**Fig. 1**).

The use of surface electromyographs requires precise information on the normal average values of average normality of different age groups and of the muscular biopotentials, both for agonist and antagonist muscles, with particular reference to the temporalis, masseter, suprahyoid and sternocleidomastoid muscles. Several studies have compared the outcomes of adults with adults,^{2–6} children with adults⁷ and children with children,^{8–13} showing in every case different occlusal diseases. To date, the muscular activity of the masticatory complex in healthy children of different ages with a physiological dental occlusion has not been considered.

The present study was aimed at evaluating the homogeneous myoelectric activity of the maxillofacial area and at identifying the myodynamic muscu-

lature balance (masseter, temporalis and suprahyoid muscles) in children of different ages with a physiological dental occlusion. Physiological dental occlusion was regarded as an Angle Class I relationship and no clinical symptoms, temporomandibular disorders, cross bite, deep bite, open bite or bruxism. The null hypothesis was that myoelectric activity in children is associated with age, which is the reason 2 age groups were selected.

Materials and methods

Sixty children, 30 aged 7–9 years and 30 aged 10–12 years, with physiological dental occlusion, underwent an electromyographic examination. The bioelectric potentials of the left and right temporalis, masseter, suprahyoid and sternocleidomastoid muscles were evaluated with the BioKeyNet surface electromyograph (Bioket, San Benedetto del Tronto, Italy). The biopotentials of the muscles were recorded using single-use surface electrodes, taking into account the recommendations of various authors.^{1, 14, 15}

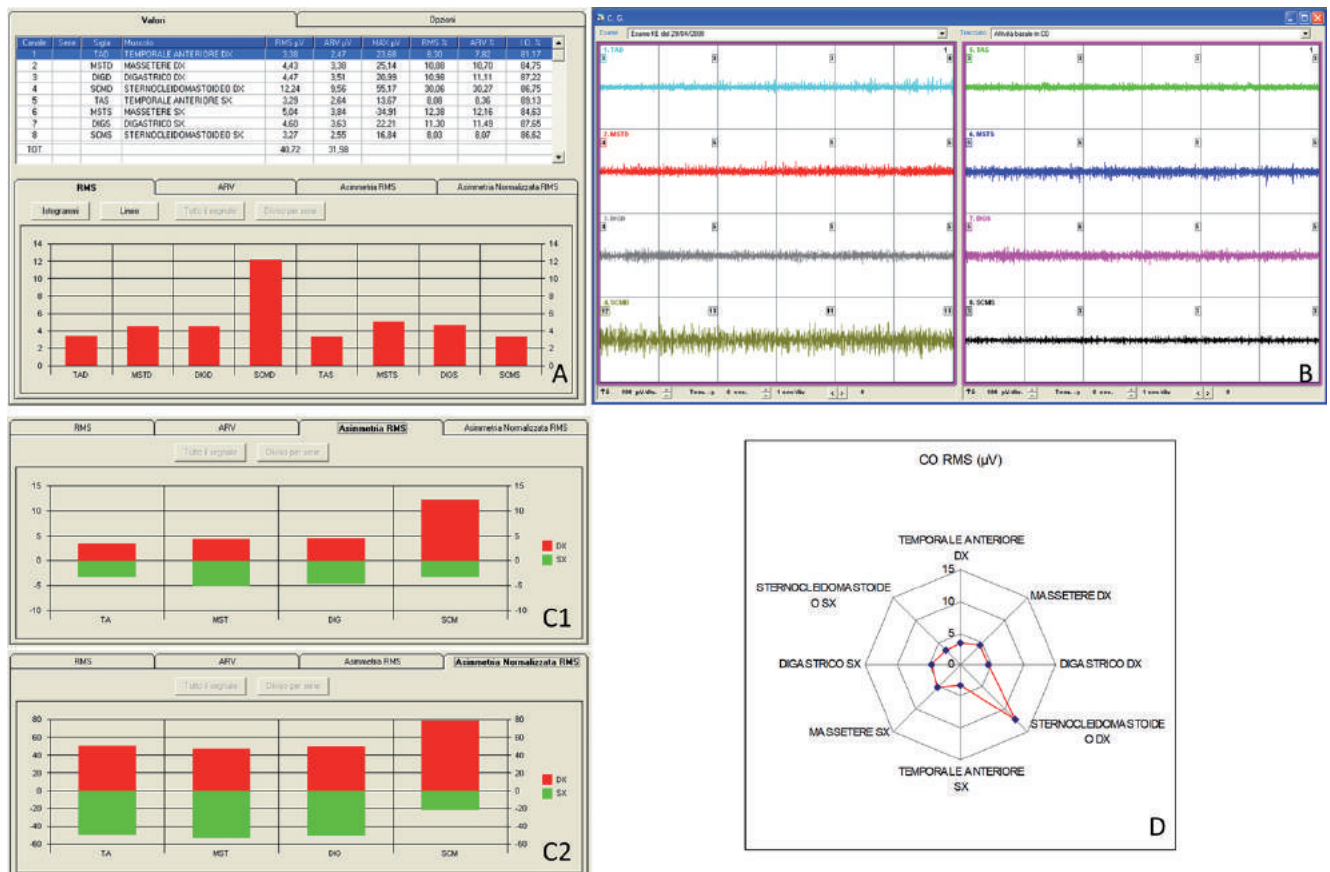


Fig. 2



Fig. 3

Muscle ratio	RMS		P value
	Right	Left	
Temporalis + masseter	256.5 ± 9.0	254.0 ± 7.3	> 0.05
Suprahyoid	27.3 ± 3.2	31.6 ± 3.7	> 0.05
Ratio ϕ mass.tempor./ ϕ suprahyoid	9.4	8.0	N/A
Sternocleidomastoid	23.4 ± 4.2	19.7 ± 3.2	> 0.05
Muscle ratio	ARV		P value
	Right	Left	
Temporalis + masseter	156.1 ± 5.0	156.7 ± 4.1	> 0.05
Suprahyoid	19.0 ± 2.6	23.8 ± 3.0	> 0.05
Ratio ϕ mass.tempor./ ϕ suprahyoid	8.2	6.6	N/A
Sternocleidomastoid	8.5 ± 0.9	10.9 ± 1.1	> 0.05

ϕ Mass.tempor. = total value of biopotentials of temporalis and masseter muscles.

ϕ Suprahyoid = mean values of biopotentials of the suprahyoid muscles.

Table 1:
Myodynamic balance of maxillofacial muscles at the time of dental clenching at maximum effort in 7- to 9-year-old children 7-9 years old with physiological occlusion (RMS and ARV in μ V).

Muscle ratio	RMS		P value
	Right	Left	
Temporalis + masseter	374.8 ± 15.5	354.0 ± 16.4	> 0.05
Suprahyoid	23.4 ± 1.9	22.4 ± 2.1	> 0.05
Ratio ϕ mass.tempor./ ϕ suprahyoid	16.0	15.8	N/A
Sternocleidomastoid	24.3 ± 2.9	22.9 ± 3.5	> 0.05
Muscle ratio	ARV		P value
	Right	Left	
Temporalis + masseter	242.7 ± 11.7	226.7 ± 10.2	> 0.05
Suprahyoid	15.8 ± 1.3	15.4 ± 1.5	> 0.05
Ratio ϕ mass.tempor./ ϕ suprahyoid	15.3	14.7	N/A
Sternocleidomastoid	15.3 ± 2.1	16.2 ± 1.8	> 0.05

ϕ Mass.tempor. = total value of biopotentials of temporalis and masseter muscles.

ϕ Suprahyoid = mean values of biopotentials of the suprahyoid muscles.

Table 2:
Myodynamic balance of maxillofacial muscles at the time of dental clenching at maximum effort in 10- to 12-year-old children with physiological dental occlusion (RMS and ARV in μ V).

On the skin in the motor area of the muscle under examination, pre-gelled self-adhesive electrodes based on silver chloride were fixed parallel to the muscular fibers, with an interelectrode distance of 22 mm. The configuration of the input channels of the surface electromyograph is of the differential type: (i) the poten-

tial difference between the positive electrode and the negative electrode is detected; (ii) a reference electrode (ground) is placed in a zone nonelectrically connected to the points to be monitored. The bioelectric signal arising from the muscle fibers, when the skin is reached, is detected by the electrodes and then ampli-

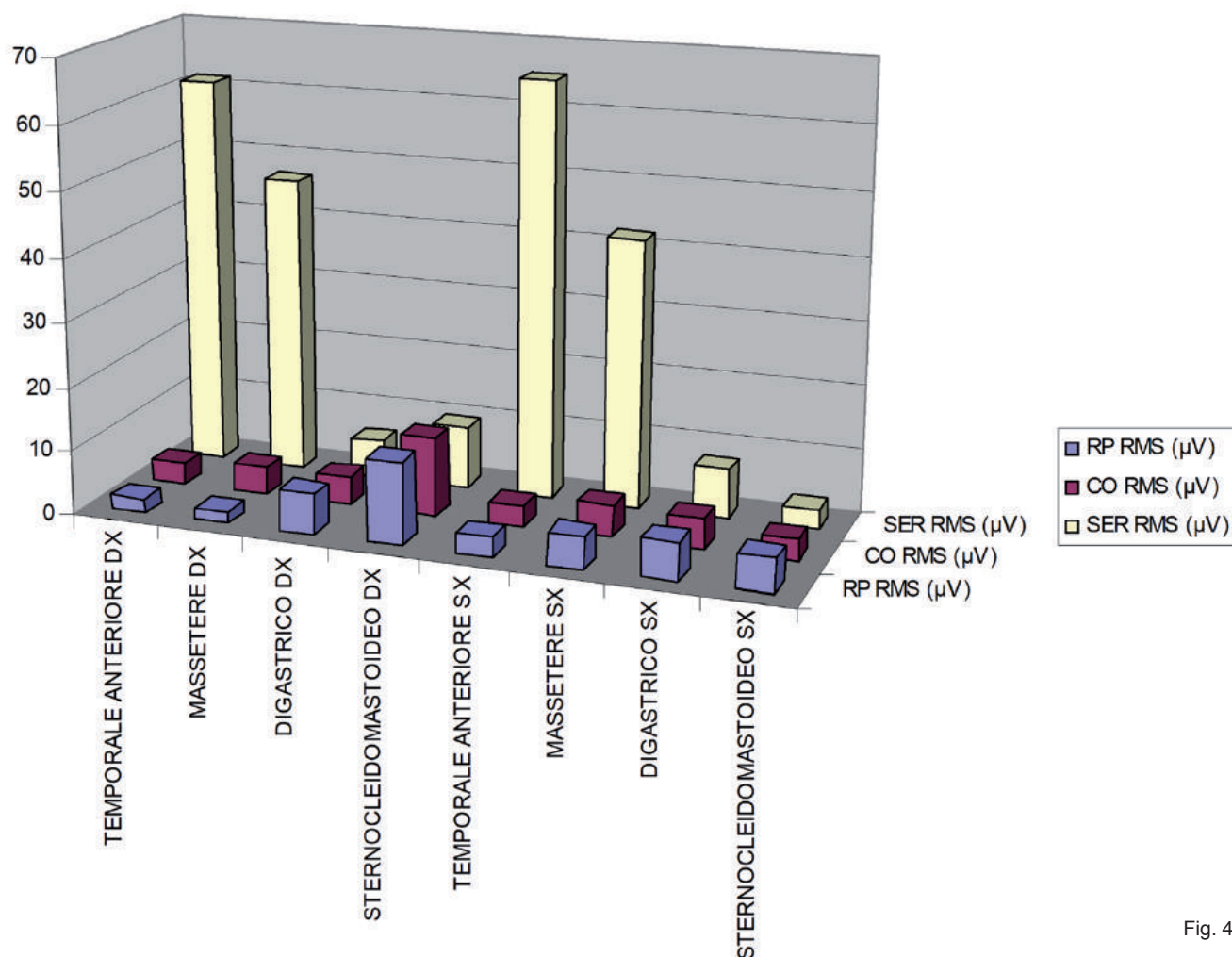


Fig. 4

Indexes	RMS		ARV	
Muscles	Right	Left	Right	Left
Temporalis	125.4 ± 9.8	143.1 ± 7.3	91.4 ± 6.5	93.6 ± 4.5
Masseter	131.1 ± 9.2	111.0 ± 7.5	64.7 ± 3.9	63.1 ± 3.8
Suprahyoid	27.3 ± 3.2	31.6 ± 3.7	19.0 ± 2.6	23.8 ± 3.0
Sternocleidomastoid	23.3 ± 4.2	19.7 ± 3.2	8.5 ± 0.9	10.9 ± 1.1

Table 3: Myodynamic balance of maxillofacial muscles at the time of dental clenching at maximum effort in 7- to 9-year-old children with physiological dental occlusion (RMS and ARV in μV).

Indexes	RMS		ARV	
Muscles	Right	Left	Right	Left
Temporalis	144.6 ± 13.7	144.9 ± 15.2	94.5 ± 9.0	92.7 ± 9.9
Masseter	230.2 ± 22.7	209.6 ± 18.2	148.2 ± 14.7	134.0 ± 11.7
Suprahyoid	23.4 ± 1.2	22.4 ± 2.2	15.8 ± 1.3	15.4 ± 1.5
Sternocleidomastoid	24.3 ± 2.9	22.9 ± 3.5	15.3 ± 2.1	16.3 ± 1.8

Table 4: Myodynamic balance of maxillofacial muscles at the time of dental clenching at maximum effort in 10- to 12-year-old children with physiological dental occlusion (RMS and ARV in μV).

fied and filtered (elimination of disturbances). The bioelectric signal is acquired, converted into digital form and transmitted to the computer for real-time display on the monitor.

The sEMG analysis was performed using the following functional tests:

1. mandible in relative physiological rest state, that is, teeth not in contact and lips just in contact (**Fig. 1**);
2. mandible in physiological position of occlusion, that is, teeth in contact (**Fig. 2**); and
3. mandible in voluntary clenching to the maximum effort (**Fig. 3**).

The main index of the functional state of a muscle is the value of the amplitude of its biological potential. Currently, 2 average amplitude indices, root mean square (RMS) and average rectified value (ARV), are mainly used. The maximum amplitude of the electromyographic signal is measured from the maximum positive peak to the maximum negative peak. The individual measured values can be processed to obtain the mean value of the absolute value with respect to the period. This index is the mean value of the adjusted signal (ARV), and it is usually expressed in μV .^{4, 5} The RMS index represents the value of a continuous voltage that develops a power equivalent to that of the electromyographic signal (alternating voltage). This index is calculated as the square root of the mean quadratic value of the electromyographic signal, and it is expressed in μV . Most of the other indexes, calculated according to the software, are derived from the ARV and RMS amplitude indices. The following electromyographic indices^{4, 5} were analyzed:

- RMS of biopotentials (expressed in μV);
- ARV of biopotentials (expressed in μV);
- total bioelectric activity (Total index, expressed in μV): the sum of all the ARV or RMS indices related to the bioelectric activity of the right and left muscles;
- participation in the bioelectric activity by each muscle in question expressed in % (calculated according to both the ARV and RMS indices)—the calculation of these participation indices was performed by dividing the bioelectric activity index of each muscle (in ARV or RMS) for the total index and subsequently multiplying by 100; and

- maximum amplitude of biopotentials index (Max; expressed in μV).

The results of the present study were statistically analyzed using BioStat software (AnalystSoft). An $\alpha < 0.05$ was used.

Results

Tables 1 and 2 show the sum parameters of the left and right temporalis, masseter, suprahyoid and sternocleidomastoid muscles (**Fig. 4**). These parameters have been taken from **Table 3** for **Table 1** and from **Table 4** for **Table 2**, respectively.

The data showed that, in 7- to 9-year-olds with physiological dental occlusion, the position of the mandible at the time of voluntary clenching at maximum effort can be normal only if the total value of the masticatory muscles (RMS; temporalis and masseter) is within the limits of $256.5 \pm 9.0 \mu\text{V}$ on the right and $254.0 \pm 7.3 \mu\text{V}$ on the left, and of the suprahyoid (digastric) muscles within $27.3 \pm 3.2 \mu\text{V}$ on the right and $31.6 \pm 3.7 \mu\text{V}$ on the left. The ratio of the temporalis and masseter muscles to the suprahyoid muscles was 9.4 times on the right and 8.0 on the left for the RMS index, and 8.2 and 6.6 times, respectively, for the ARV index. It should be noted that, in the case of normal posture, the biopotentials of the sternocleidomastoid muscles were within the limits of $23.4 \pm 4.2 \mu\text{V}$ on the right and $19.7 \pm 3.2 \mu\text{V}$ on the left.

The normal position of the jaw at the time of voluntary clenching at maximum effort in the 10- to 12-year-olds was possible when the total value of the temporalis and masseter muscles was within the limits of $374.8 \pm 15.5 \mu\text{V}$ on the right and $354.0 \pm 16.4 \mu\text{V}$ on the left, of the suprahyoid muscles was within $23.4 \pm 1.9 \mu\text{V}$ on the right and $22.4 \pm 2.1 \mu\text{V}$ on the left. The ratio of the temporalis and masseter muscles to the suprahyoid muscles was 16.0 times on the right and 15.8 times on the left for the RMS index, and 15.3 and 14.7 times, respectively, for the ARV index. In the 10- to 12-year-olds in normal posture, the biopotentials of the sternocleidomastoid muscles were within the limits of $24.3 \pm 2.9 \mu\text{V}$ on the right and $22.9 \pm 3.5 \mu\text{V}$ on the left. It should be noted that, in both age groups, no reliable differences were found between the parameters of the masseter, temporalis,

Age (years)	Coordination coefficient	
	Right	Left
7–9	$\frac{256.5 - 27.3}{256.5 + 27.3} = \frac{229.2}{283.8} = 0.81$	$\frac{254.0 - 31.6}{254.0 + 31.6} = \frac{222.4}{285.6} = 0.78$
10–12	$\frac{374.8 - 23.4}{374.8 + 23.4} = \frac{351.4}{398.2} = 0.88$	$\frac{354.0 - 22.4}{354.0 + 22.4} = \frac{331.6}{376.4} = 0.88$

Table 5: Coordination coefficient values in relation to the RMS index at the time of voluntary clenching at maximum effort in children aged 7–9 and 10–12 years with physiological occlusion.

suprahyoid and sternocleidomastoid muscles on the right and on the left, respectively.

Table 5 shows that the coordination coefficient for the maxillofacial area muscles evaluated at the time of voluntary clenching at maximum effort in the 7- to 9-year-olds was within the limits of 0.81 on the right and 0.78 on the left. In the 10- to 12-year-olds, at the end of the period of transition from primary dentition, the coordination coefficient was higher compared with the 7- to 9-year-olds, and it was the same (0.88) for both sides. This indicates that, toward the end of the replacement of the primary dentition, the muscles of the maxillofacial area on the left and on the right work in a homogeneous regimen.

Discussion

The present study evaluated the homogeneous muscular activity in the maxillofacial area and identified myodynamic balance in children with physiological dental occlusion. The mean biopotential values were identified of the masseter, temporalis and suprahyoid muscles, which participate directly in the retention of the physiological position of the resting jaw at the time of voluntary clenching at maximum effort. The mean values of the biopotentials of the muscles were assessed, as was the muscular myodynamic balance on the right and on the left. It was seen that the homogeneity of the muscular activity improves with age.

It is very important to establish the myodynamic balance of the muscles of the maxillofacial area between the right and left and compare them, since they condition the normal position (normognathic) of the jaw. In unbalanced conditions, the mandible may be

displaced either to the right or to the left, as well as in a distal or mesial direction. In addition, to study the myodynamic balance of the muscles of the maxillofacial area, it is necessary to have information on the

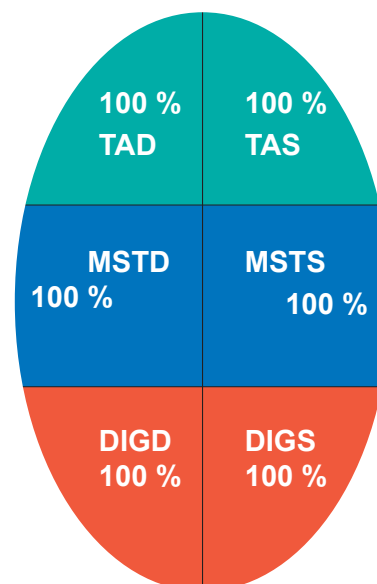


Fig. 5

homogeneous activity of the agonist and antagonist muscles, both in physiological or pathological conditions.

The coordination coefficient provides a value that expresses the balance of the muscles between the right and left in rest position and at maximum clenching. The myodynamic equilibrium and homogeneous muscular activity are illustrated in **Figure 5**, where the parameters of the masseter, temporalis and suprahyoid muscles in children with physiological dental occlusion are considered to be entirely normal. The intensity of the color changes according to the sEMG parameters and the deviation from the mean.

As mentioned before, previous studies on children compared patients with diseases. However, in those studies, the values in μV were assessed for dental clenching with cotton rolls and expressed as percentages of maximum voluntary clenching. This means that a direct comparison with the data from the present study is difficult. However, it should be considered that the use of cotton rolls during maximum clenching should increase the values in μV compared with maximum clenching without cotton rolls. Nevertheless, varying findings have been reported in several studies performed in children. In a clinical study,⁸ for example, the electromyographic activity and thickness of the right masseter, left masseter, right temporalis and left temporalis muscles and bite force in children with temporomandibular disorders were evaluated. The bite force was lower in the temporomandibular disorders group than in the control group. In another study,⁹ the electromyographic activity of the masseter and anterior portion of the temporalis muscles was evaluated in children with and without sleep bruxism. Children with sleep bruxism showed no significant difference in EMG of masticatory muscles at rest and in maximal intercuspal positions of the mandible compared with the control group.

In another study,¹⁰ the electromyographic activity of the temporalis and masseter muscles was evaluated in children with mixed dentition and a mean age of 8.6 years. All the children were undergoing rapid maxillary expansion with a bonded rapid maxillary expansion appliance. The electromyographic analysis showed that the activity of the temporalis and masseter muscles increased significantly when the expansion appliance was removed. During dental clenching with cotton rolls, the values in μV expressed as percentages of the maximum voluntary clenching increased from $\sim 112\text{--}113\ \mu\text{V}$ to $143\text{--}149\ \mu\text{V}$ for the masseter muscles and from $\sim 102\ \mu\text{V}$ to $116\text{--}135\ \mu\text{V}$ for the temporalis muscles. In the present study, in children with physiological dental occlusion, the data were higher during maximum voluntary clenching, $256.5\ \mu\text{V}$ for the temporalis and masseter muscles. This might indicate that the removal of the rapid maxillary expansion appliance in the previously discussed study¹⁰ did not permit normal myoelectric activity of these muscles.

In conclusion, the present study provided the range of physiological function of the masticatory and ster-

nocleidomastoid muscles that children aged 7–9 and 10–12 should present in a myographic examination. Any deviation from these values suggests the presence of occlusal and/or postural problems, and an appropriate intervention to reach the values indicated in the present study should be considered.

Competing interests

The authors declare that they have no competing interests.

Legends

Fig. 1 – (A) Data acquired digitally and represented in the form of tables and histograms. Signal evaluated in relative physiological rest state. (B) Raw signal in relative physiological rest state. (C1) Histogram representation of asymmetrical root mean square signals in relative physiological rest state; (C2) signals normalized. (D) Further graphic representation of the mandible signals in relative physiological rest state.

Fig. 2 – (A) Representation in tables and histograms of the signal in the physiological position of occlusion (teeth in contact). (B) Raw signal in physiological dental occlusion position (teeth in contact). (C1) Histogram representation of asymmetrical root mean square signals in physiological dental occlusion position (teeth in contact); (C2) signals normalized. (D) Further graphic representation of the mandible signals in physiological dental occlusion position (teeth in contact).

Fig. 3 – (A) Representation in tables and histograms of the signal in voluntary clenching at maximum effort. (B) Raw signal in voluntary clenching at maximum effort. (C1) Histogram representation of asymmetrical root mean square signals in voluntary clenching at maximum effort; (C2) signals normalized. (D) Further graphic representation of the mandible signals in voluntary clenching at maximum effort.

Fig. 4 – Summary representation in a histogram of the functional tests performed.

Fig. 5 – Myodynamic equilibrium and homogeneous muscular activity. TAD = Right anterior temporalis; TAS = Left anterior temporalis; MSTD = Right masseter; MSTS = Left masseter; DIGD = Right digastric; DIGS = Left digastric. The intensity of the color

changes according to the sEMG parameters and the deviation from the mean. In the present diagram, the color intensity is 100% for each parameter.

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- درمانی آسان برای بستن دائمی اپکس در دندان های شیری