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ORTHODONTICS HIGHLIGHTS

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DIFFICULTY IN DIAGNOSING INTERPROXIMAL CARIES USING RADIOGRAPHS WITH ORTHODONTIC APPLIANCE

The presence of a fixed orthodontic appliance makes maintaining oral hygiene, particularly through flossing, difficult. The accumulation of food in the interproximal space causes interproximal caries. These lesions are difficult to diagnose, requiring auxiliary resources to detect them. Periapical radiographs are the preferred method to assess the presence of interproximal caries; however, the presence of an orthodontic appliance complicates this task. Unfortunately, the literature offers no evidence regarding whether or not orthodontic appliances impede the diagnosis of caries. Recently, two Turkish researchers published a study[1] that aimed to investigate the influence of orthodontic materials on the assessment of proximal caries using periapical radiography. Forty non-cavitated and restoration-free human premolars and molars, ranging from healthy teeth to teeth with varying

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degrees of caries lesions, were incorporated into silicon blocks. Periapical radiographs (Fig. 1) were fused from two orthodontic materials (three brackets and two arches). After conducting the study, the authors concluded that the combination of metal brackets and stainless steel arches impedes the diagnosis of interproximal caries using periapical radiography. The authors recommend removing the arches during radiographic imaging, to improve the detection of caries.

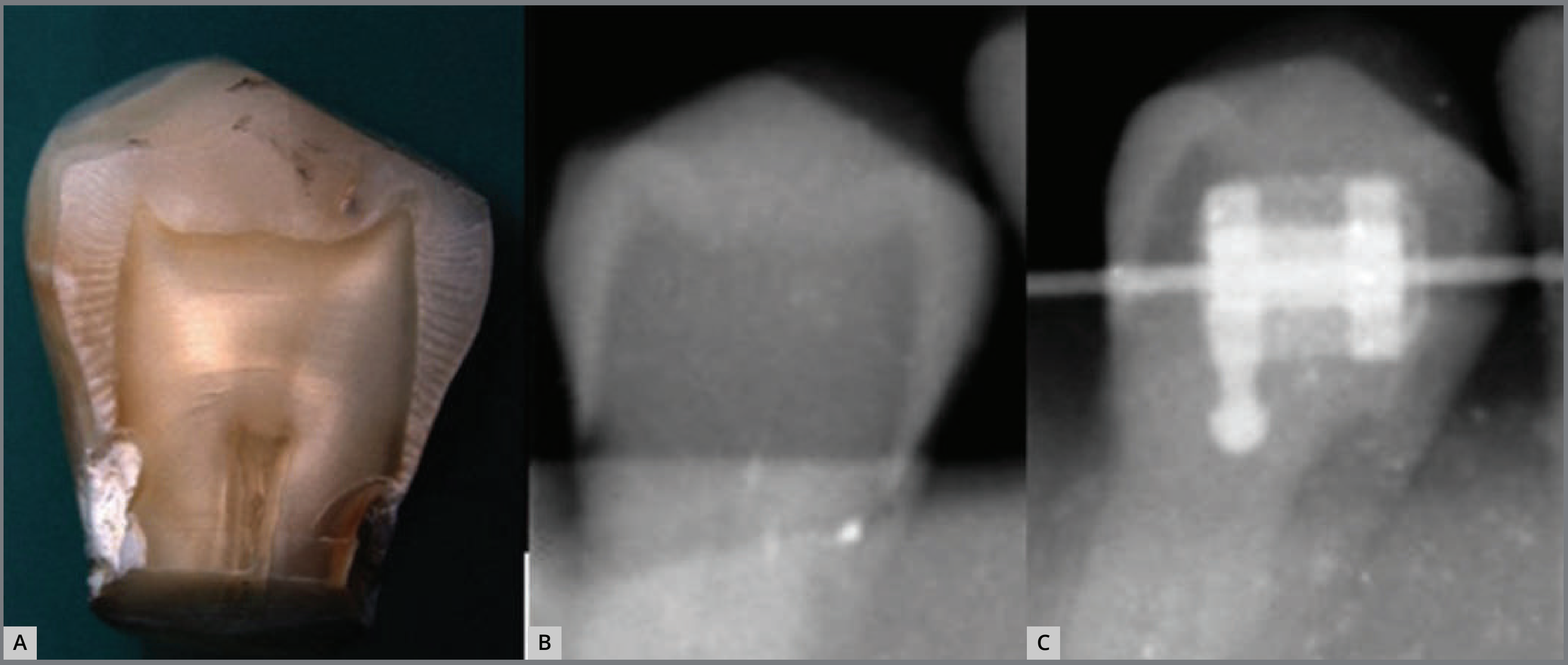

Figure 1: Images of the premolar tooth: **A)** histological image obtained using a microscope, **B)** periapical radiographic image, **C)** periapical radiographic image of the tooth with bracket and stainless steel wire. Source: Isman et al.[1], 2020.

OBESITY AND INCREASED FACIAL GROWTH: IS THERE A RELATIONSHIP?

Obesity has become a global public health epidemic, affecting people of all races, sexes, and ages. The adverse health effects of obesity, including heart disease, respiratory dysfunction, and diabetes, are well reported. Childhood obesity is also associated with decreased growth hormone secretion and the early onset of puberty and pubertal growth spurts. Thus, it is logical to ask whether childhood obesity influences facial and mandibular size and shape. To answer this question, American researchers developed a study[2] where they retrospectively reviewed the pretreatment records of 181 patients. Patients' body mass index (BMI) was calculated, and twenty-two reference points on their lateral cephalometric radiographs were analyzed (Fig 2). The reference data set was analyzed as a whole (facial shape), and a subset of reference points was used to study the mandibular shape alone. The authors found that most of their results did not support a relationship between high BMI and facial shape. However, larger facial skeleton sizes were found in the sample in children with high BMI, providing provisional evidence that childhood obesity can accelerate facial growth.

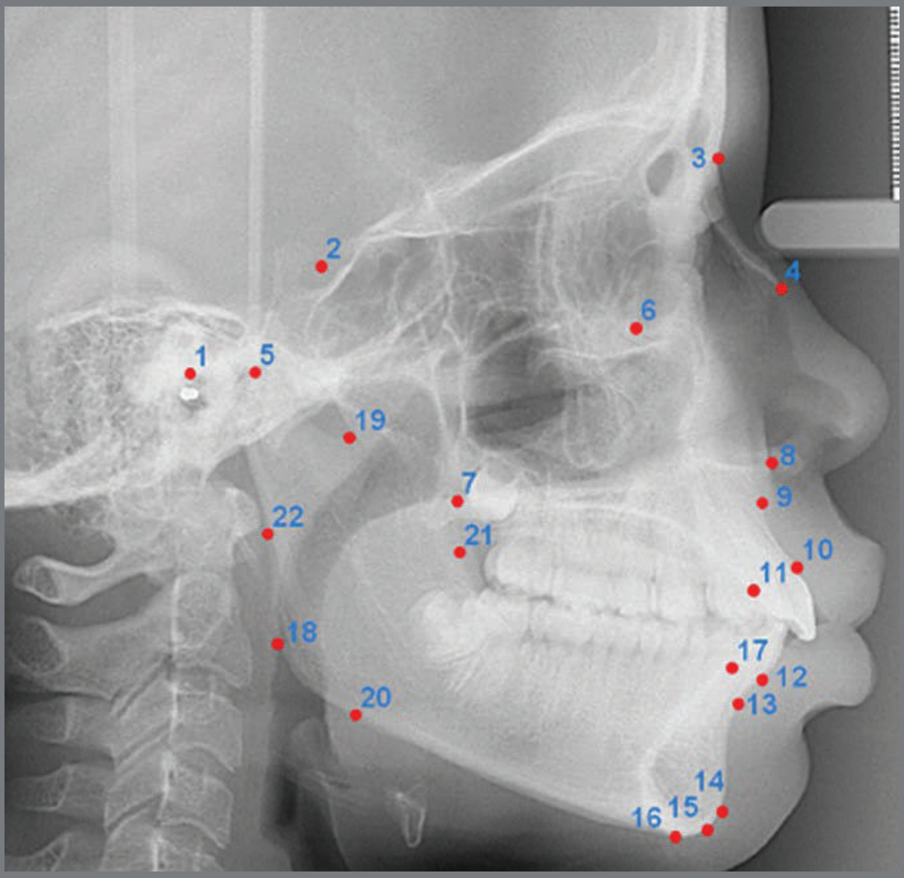

Figure 2: Cephalometric reference points used in the study. Source: Gordon et al.[2], 2021.

SMARTPHONE APPS HELP IMPROVE ORAL HYGIENE IN ORTHODONTIC PATIENTS

Obtaining proper oral hygiene when using a fixed orthodontic appliance is difficult. Thus, innovative oral health promotion programs must be developed to help improve patients' oral health. Although studies have evaluated the impact of using smartphone applications to motivate orthodontic patients to clean their teeth correctly, there is no consensus on the efficacy of these applications. In response, Indian researchers carried out a systematic review of the literature[3] to evaluate the effectiveness of smartphone applications in improving the oral hygiene of patients undergoing fixed orthodontic treatment.

The authors conducted a systematic search in the PUBMED/MEDLINE, CINAHL, EMBASE, COCHRANE, PROQUEST, Google Scholar, and Web of Science databases. This method yielded 154 studies after removing duplicates. Based on the eligibility criteria, only five studies were included in the data extraction phase. The results revealed that smartphone apps have a significant short-term effect on improving oral hygiene when measured by the plaque and gingival indices, as the mean plaque index and the gingival index significantly decreased in three of the five studies.

MUSIC AT 432HZ FREQUENCY IS EFFECTIVE IN REDUCING ANXIETY IN DENTAL PATIENTS

The general population rates receiving dental care as one of the five most feared scenarios. Music therapy has been used as a non-pharmacological method to control anxiety before dental treatment due to its action on the sympathetic nervous system, where it reduces adrenergic activity and neuromuscular activation, thereby reducing patient anxiety. According to the International Organization for Standardization (ISO), the pitch pattern established for the musical note A is 440 Hz. Tones at a tuning frequency of 440 Hz can be uncomfortable, irritating, and unpleasant, while tone intervals at the tuning frequency of 432 Hz are peaceful, pleasant, and harmonious. Brazilian researchers, in partnership with Chilean researchers, developed a study[4] to determine how these frequencies impacted patients' anxiety before dental treatment. To this end, they conducted a randomized clinical trial with 42 patients with moderate anxiety levels. Patients were divided into three groups: those who listened to music for 15 minutes at 432 Hz (n = 15) or 440 Hz (n = 15) and a control group without music (n = 12). The CORAH Dental Anxiety Scale and salivary cortisol levels, estimated by the solid-phase enzyme-linked immunosorbent assay (ELISA), were measured and compared before and after the musical intervention for all groups. The results of the study revealed that listening to music significantly decreased levels of clinical anxiety. The authors also noted that the 432 Hz frequency effectively reduced salivary cortisol levels before tooth extraction.

THE PRESENCE OF MALOCCLUSION AFFECTS THE VOICE

Speech, the production of sounds through the interactions of the articulator and phonetic systems, is the most common form of communication. Speech production involves four processes: breathing, phonation, resonance, and articulation. In the articulation phase, speech sounds are produced by dynamic movements of the tongue, lips, and teeth. Thus, the presence of malocclusion could, hypothetically, alter speech.

To test this hypothesis, Turkish researchers developed a study[5] that evaluated the acoustic properties of the sound /s/ in individuals with different types of malocclusion. In this study, 60 patients were divided into three groups based on malocclusion (Class I, II, and III). Then, cephalometric tracings were obtained from cephalometric radiographs. The sound /s/ was isolated for analysis, and the authors concluded that the sound /s/ was affected by malocclusion due to changes in the joint site. The authors suggested referring patients with Class III malocclusion in the initial period to help them produce an acoustically ideal sound.

REFERENCES

1. Isman O, Kayar S. The effects of orthodontic materials on the accuracy of periapical radiography-based caries detection. Oral Radiol. 2020 Oct;36(4):349-55.

2. Gordon LA, Miller SF, Caplin J, Galang-Boquiren MT, Alrayyes S, Nicholas CL. Childhood obesity may accelerate timing of human facial growth. Archives of Oral Biology. 2021 Jan;121:104964.

3. Patil S, Hedad IA, Jafer AA, Abutaleb GK, Arishi TM, Arishi SA, et al. Effectiveness of mobile phone applications in improving oral hygiene care and outcomes in orthodontic patients. J Oral Biol Craniofac Res. 2021 Jan-Mar;11(1):26-32.

4. Aravena PC, Almonacid C, Mancilla MI. Effect of music at 432 Hz and 440 Hz on dental anxiety and salivary cortisol levels in patients undergoing tooth extraction: a randomized clinical trial. J Appl Oral Sci. 2020;28:e20190601.

5. Buyuknacar GB, Gulec A. Correlation between the cephalometric measurements and acoustic properties of /s/ sound in Turkish. J Appl Oral Sci. 2020;28:e20190399.

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Ten reasons to not ignore the third molar

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ABSTRACT

Introduction: The third molars are forgotten because they are the last in the dental arch, they do not directly influence the smile and they appear only in adolescence, when they do.

Objectives: 1) to provide the clinician with a "checklist" to assess and diagnose changes to be screened in the third molar region in new patients; 2) to reveal the importance of not discharging the patient submitted to any dental treatment without first analyzing the third molars region clinically and on imaging examinations, since many diseases are associated to them.

Result: A list of 10 situations that cover all diagnostic possibilities involving the third molars is presented.

Conclusion: Adopting this protocol is a matter of habit, since the need is fundamental. The next professional assisting your patient may ask: *"Did he not request examinations for the third molars?"*.

Keywords: Third molars. Pericoronaritis. Paradental cyst. Tooth resorptions. Unerupted teeth. Dentigerous cyst.

RESUMO

Introdução: Os terceiros molares são esquecidos por serem os últimos dentes na arcada dentária, por não influenciarem diretamente no sorriso e por aparecerem apenas na adolescência — quando aparecem.

Objetivos: 1) Fornecer ao clínico um *checklist* de conferência e diagnóstico de alterações a serem checadas na região dos terceiros molares em novos pacientes; e 2) Destacar a importância de não dar alta ao paciente submetido a qualquer tratamento odontológico sem antes analisar, clínica e imagiologicamente, a região dos terceiros molares, pois muitas doenças estão a eles associadas.

Resultado: Criou-se uma lista de 10 situações que englobam todas as possibilidades diagnósticas envolvendo os terceiros molares.

Conclusão: Adotar esse protocolo é uma questão de hábito, pois a necessidade é imperiosa. O próximo profissional a atender o seu paciente vai perguntar: *“Ele não solicitou exames para os terceiros molares?”*.

Palavras-chave: Terceiros molares. Pericoronarite. Cisto paradentário. Reabsorções dentárias. Dentes não irrompidos. Cisto dentígero.

INTRODUCTION

It is not uncommon for us to examine only the tooth related to the main complaint of the patient, such as painful sensitivity, gingival recession and/or an esthetic change, or even an enamel fracture and/or a poorly fitting restoration.

It is also not uncommon to focus only on the expectation due to which the patient sought the professional, such as whitening, a facet, dental alignment or restoration.

Unfortunately, many patients finish their orthodontic treatments, even with orthognathic surgeries, with upper and/or lower third molars with anomalies of position and eruption, inducing resorptions in neighboring teeth, with pericoronitis and paradental cysts.

Ideally, after the first consultation, we should request a panoramic radiograph and periapical radiographs of the jaws. The surprise will always be present, as dental anomalies, periapical lesions, tooth resorptions, intraosseous lesions, calcific metamorphoses of the pulp, supernumerary teeth, unerupted teeth, etc.

With the images and an imaging report in hand, you will feel a complete professional in planning, and the patient will feel much reassured about the professional caring for his or her oral health. This routine will make you a happier professional!

In the third molar region, embryonic odontogenic tissues are exposed for many years to intrinsic and extrinsic environmental factors, as well as growth and lack of space, which combine and increase the possibility of problems related to anomalies of shape, position and eruption. This region should be checked for each new patient to prevent resorption, pericoronitis, paradental cysts, concrescences, cysts and odontogenic tumors. Thus, pain and mutilation are avoided, and the patient will always be close to the desired function and esthetics.

The aim of this work is to provide the clinician with a “checklist” or a protocol to assess and diagnose changes to be screened in new patients, regarding the third molar region. The other objective is to reveal the importance of not discharging the patient submitted to any dental treatment, including orthodontic treatment, before analyzing the third molars region clinically and by imaging examinations.

CHECKLIST FOR THIRD MOLARS IN ALL DENTAL PATIENTS, INCLUDING ORTHODONTIC PATIENTS

Ask yourself and your patient: where and how are the third molars. They can be:

1. Erupted and in normal occlusion with the antagonist, which is ideal and desired, yet unfortunately it does not always happen (Fig 1). If the antagonist is not present, its tendency is to extrude and cause periodontal and sensitivity problems.

2. Erupted and in normal occlusion with the antagonist, yet without distal bone space to form a healthy gingiva (Fig 1). The gingiva may be occupying the entire distal aspect of the

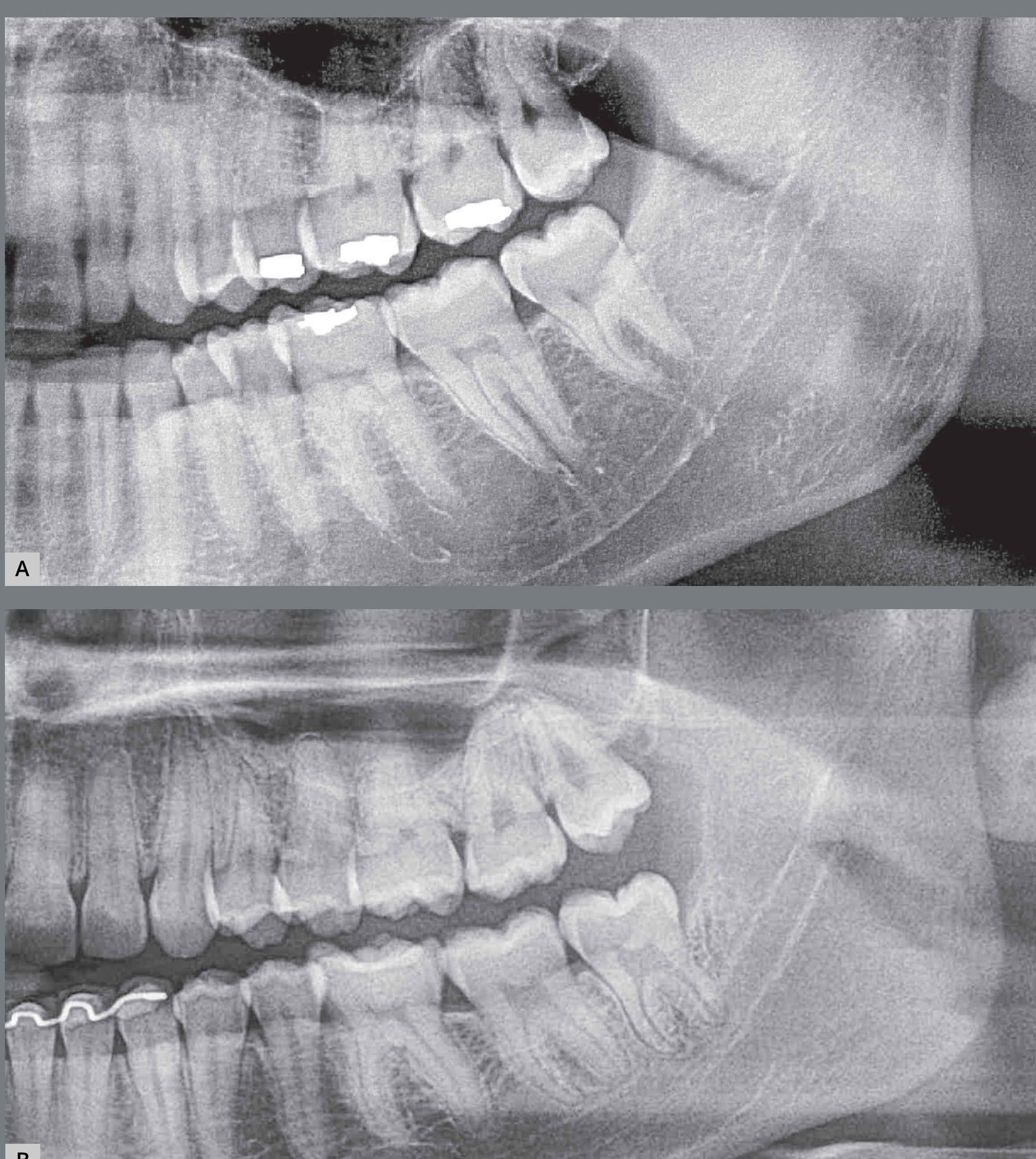

Figure 1: Third molars erupted in occlusion. Ideally, there should be gingiva distal to the third molar at the cervical level, such as in tooth #28. If there is lack of distal bone space, as in tooth #38, the gingiva is at the occlusal level, favoring the development of pericoronitis and a paradental cyst.

crown with a long gingival sulcus, with difficult hygiene. In the site there may be gingivitis, periodontitis, pericoronitis and their consequences, including contribution to halitosis and constant perception of oral bleeding, altering the sense of taste.[1,2]

3. Erupted in normal occlusion, yet with a pericoronal cap over the occlusal surface coming from the distal part of the buccal/gingival mucosa (Figs 2, 3 and 4). This pericoronal cap can be identified as a gingival operculum or it may be also called a cap.

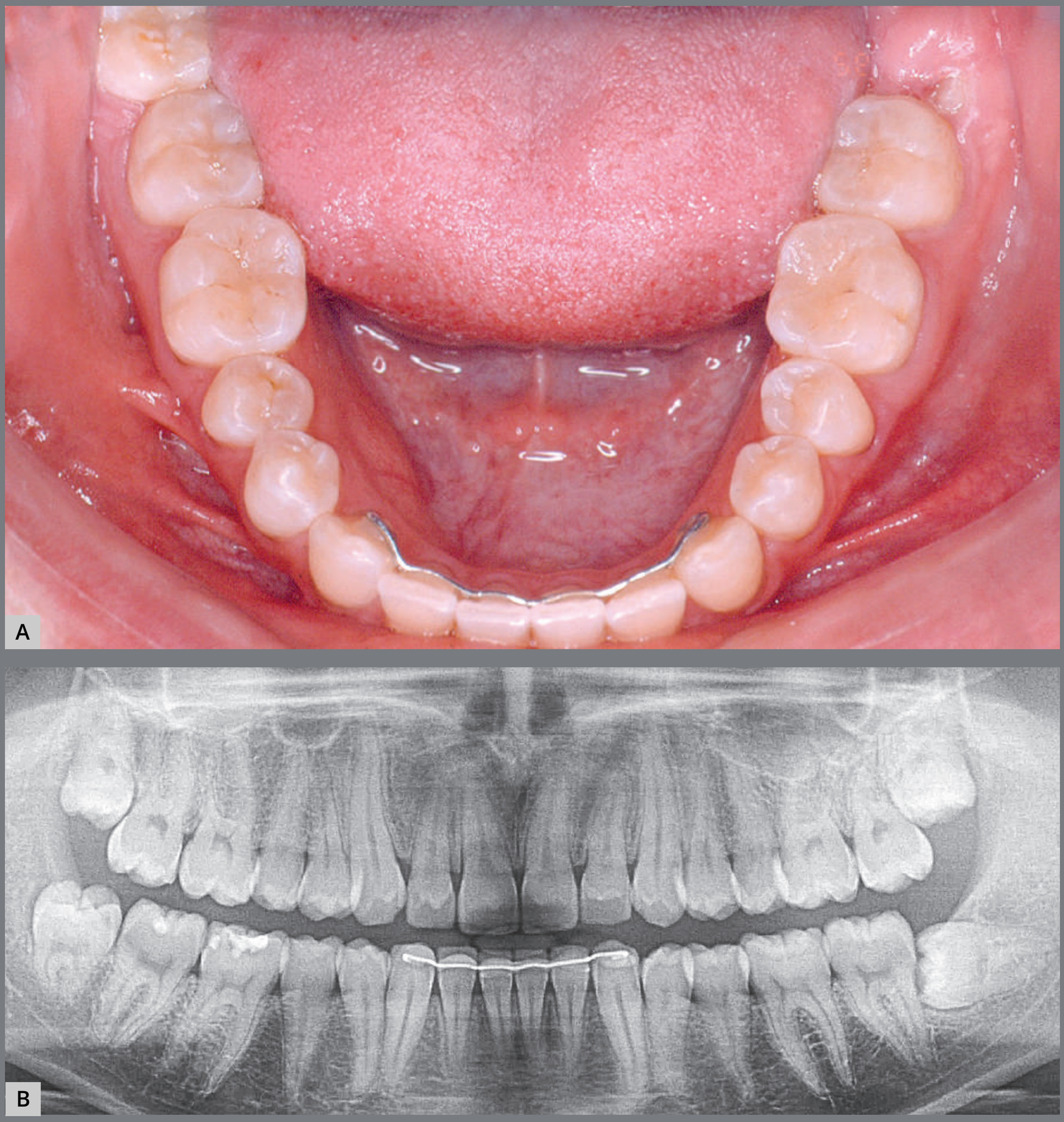

Figure 2: Lower and upper third molars with risk of pericoronitis, paradental cyst and external root resorption in the distal surface of second molars in a patient discharged from orthodontic treatment.

Figure 3: Small gingival cap or operculum in the lower third molars with aspect of normal mucosa revealing communication with the oral environment, increasing the risk of episodes of pericoronitis and development of paradental cyst. On the panoramic radiograph, the horizontal and mesially angulated position of the lower third molars reveals a risk of external root resorption in second molars.

A long interface is formed up to the distal cervical region of the tooth, accumulating microbial biofilms, food debris and predisposing the site to episodes of acute and chronic pericoronaritis alternately (Fig 5). At each episode, there is deepening and widening of this distal gingival interface and a paradental cyst is established in its distal part (Fig 6).[1,2,3,4]

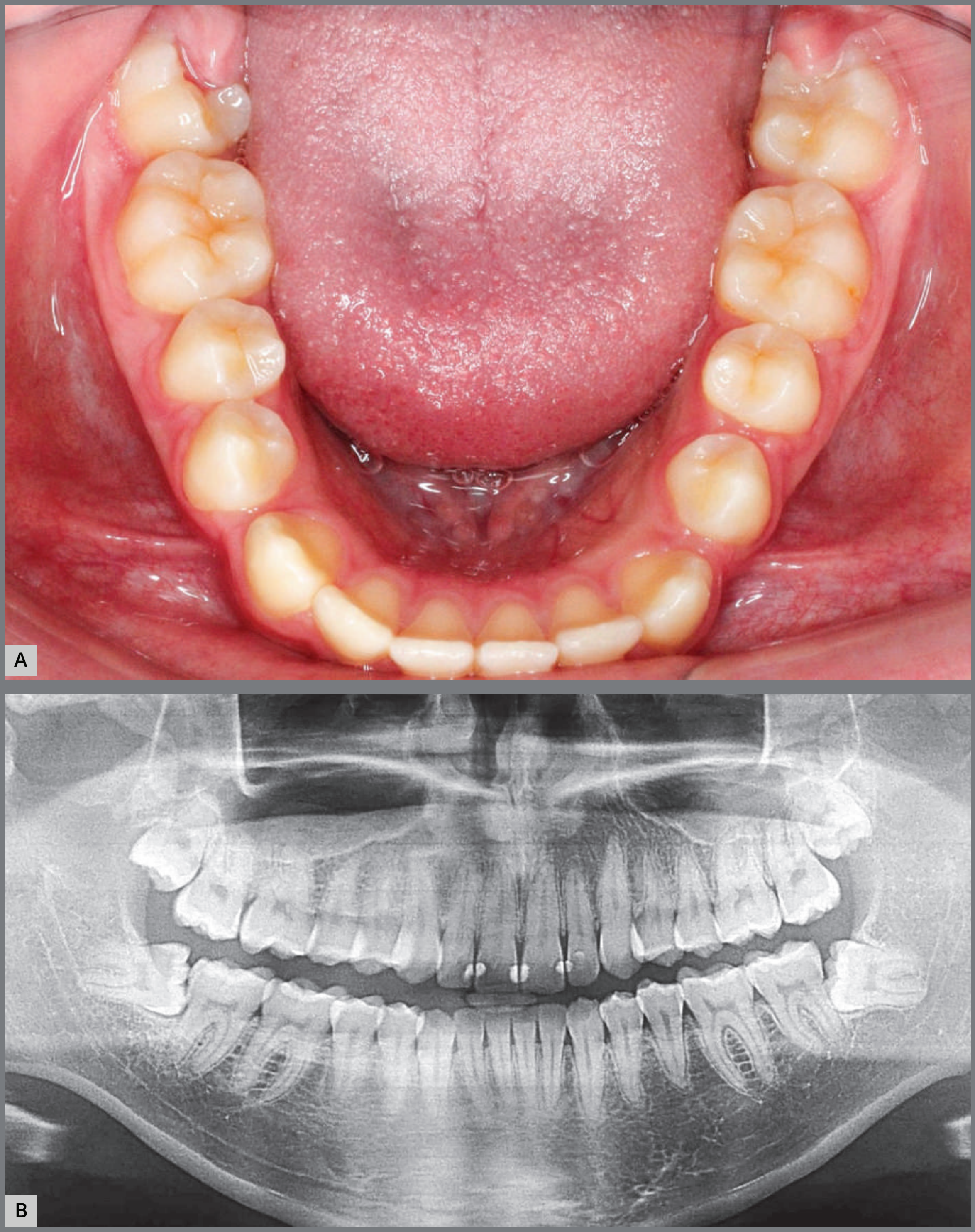

Figure 4: Hyperplastic gingival opercula or hyperplastic caps in the third molars create an interface that protects microbial biofilms, increasing the risks of pericoronaritis and a paradental cyst. On the panoramic radiograph, the horizontal and mesially angulated position of the lower third molars reveals a risk of external root resorption in the second molars.

4. Partially erupted and not impacted, despite the mesial angulation, with paradental cyst, yet still not impacting the second molar, which would prevent them from reaching the occlusal plane, greatly increasing the possibility of acute and

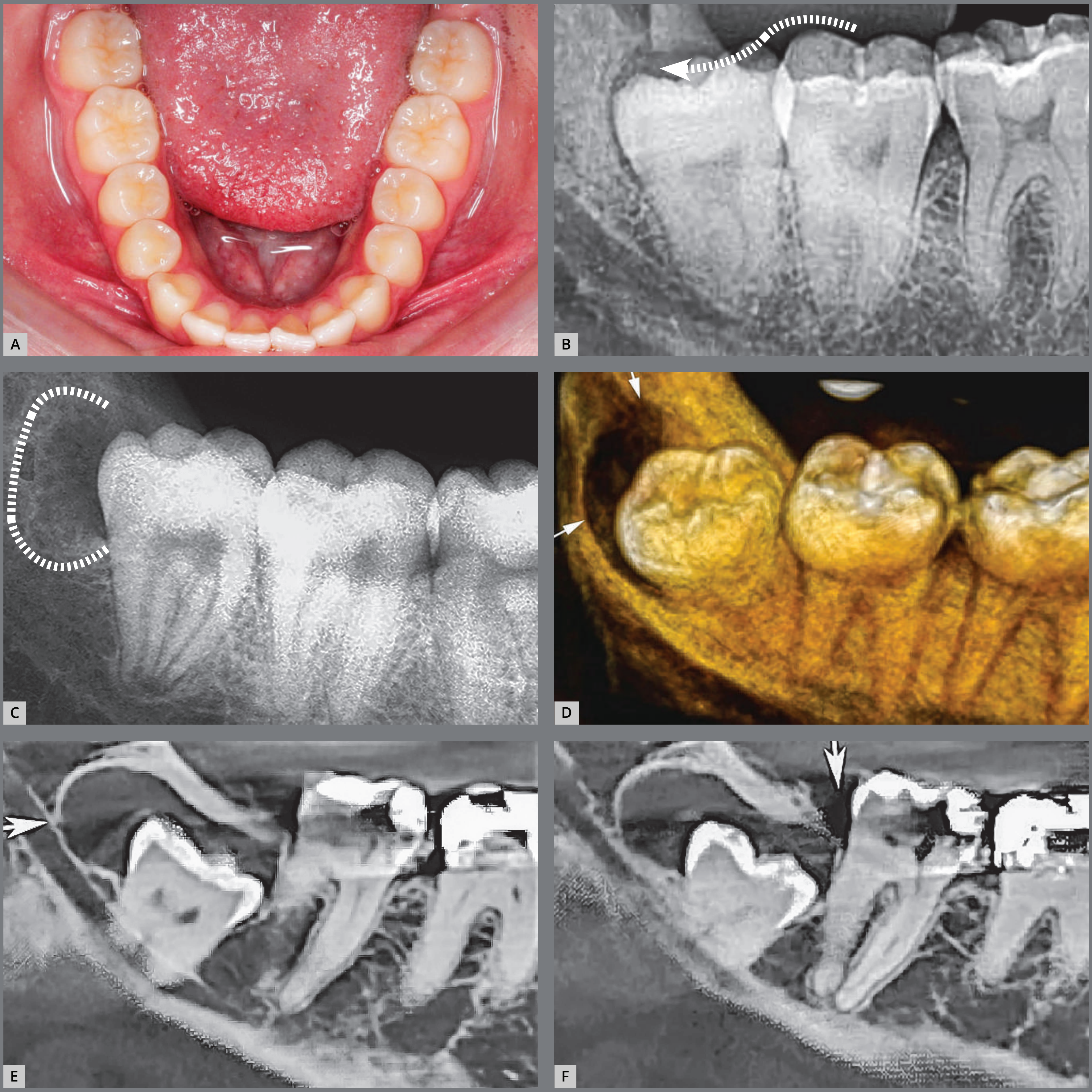

Figure 5: Bacteria and microbial biofilms infiltrate the partially erupted third molar follicle and communicates with the oral environment (dotted arrow, in **B**). Episodes of acute and chronic pericoronaritis develop, alternating with irregular distal bone resorption (dotted line, in **C**). Thus, the paradental cyst is formed (smaller arrows).

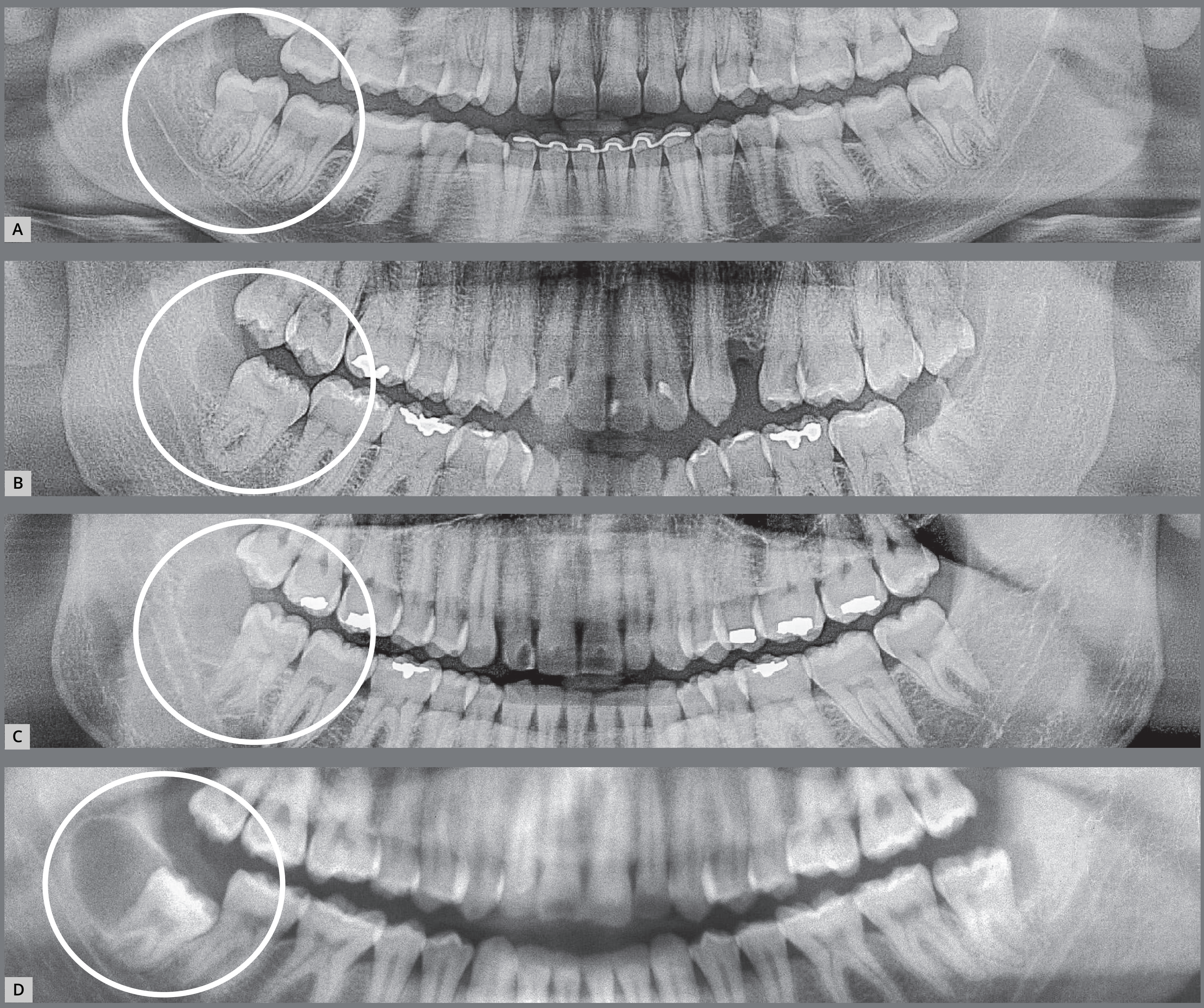

Figure 6: Paradental cysts from incipient development up to advanced occurrence on the distal surface of partially erupted lower third molars on the right side of panoramic radiographs. It is noteworthy that the patient in **A** was discharged from orthodontic treatment.

chronic pericoronaritis alternately to give rise to a paradental cyst on its distal or mesial aspect towards the mandibular base (Figs 7 and 8).[1,2,3,4] On the face opposite to that occupied by the cyst, the gingival tissues may be normal.

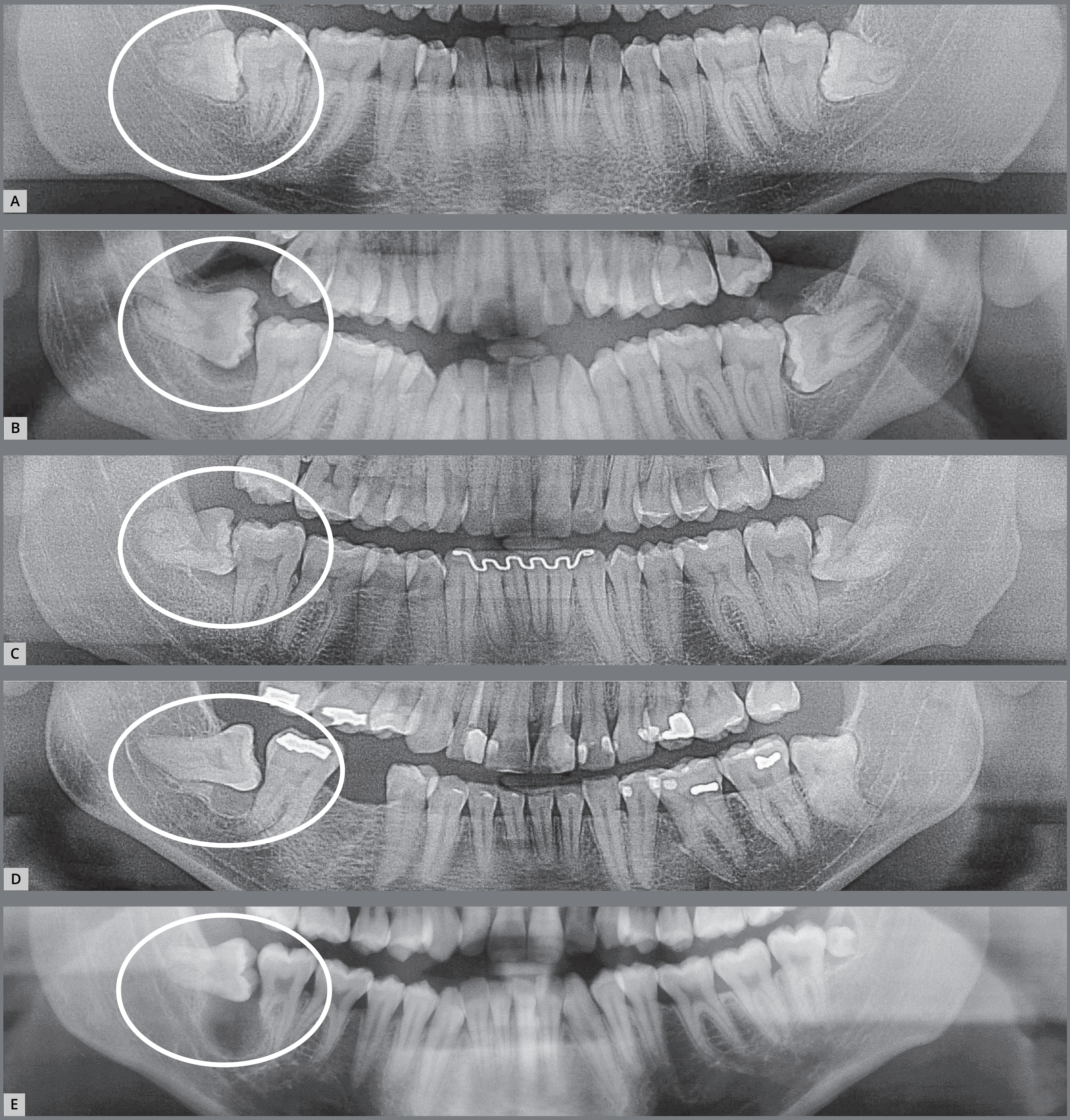

Figure 7: Paradental cysts from normal pericoronal space to the development on the mesial surface of the partially erupted lower third molars, mesially angulated and horizontalized on the right side of the panoramic radiographs. It is noteworthy that the patient in **C** was discharged from previous orthodontic treatment and was also affected on the left side.

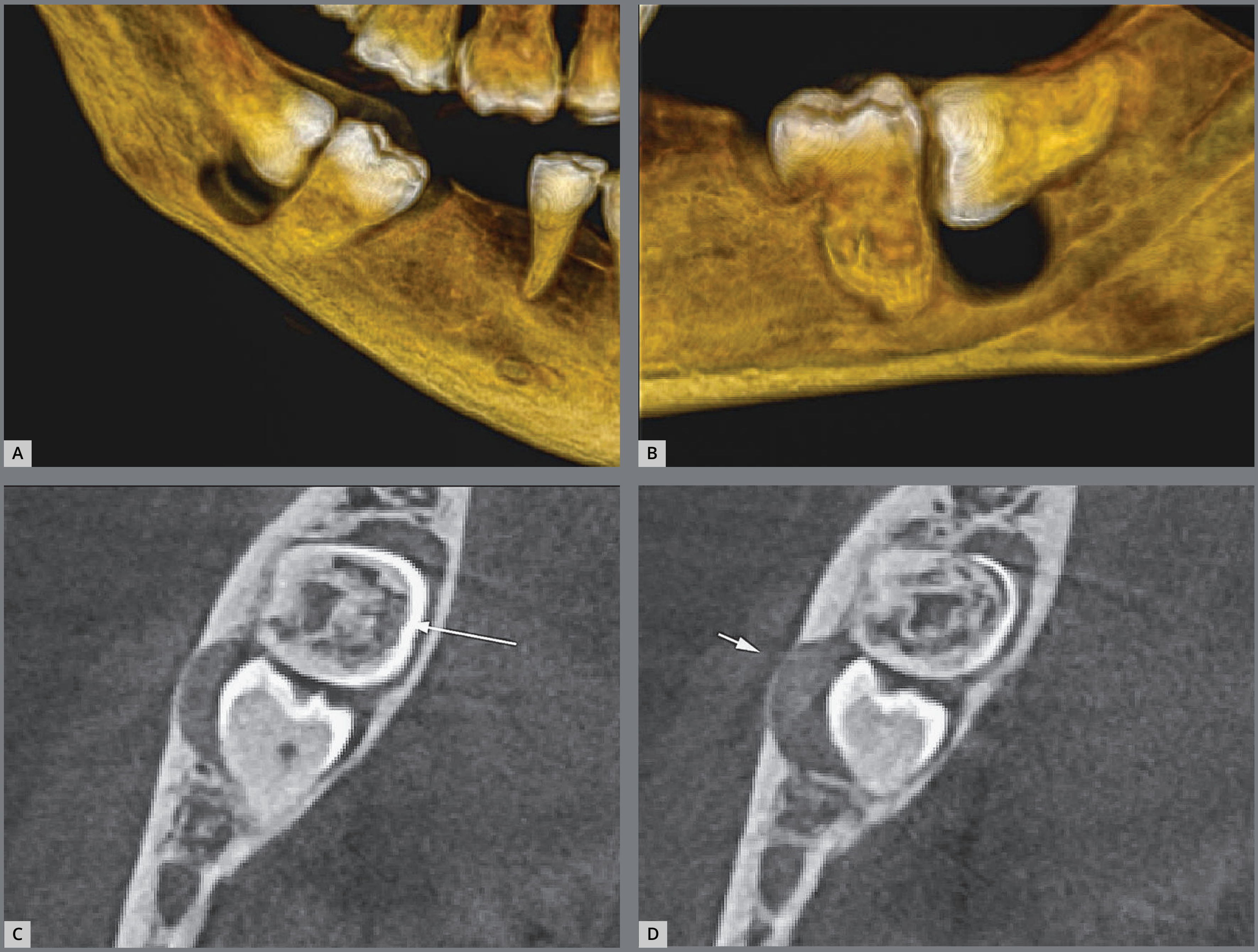

Figure 8: Mesial paradental cyst on the partially erupted lower third molar associated with partially erupted lower second molar with ankylosis and replacement resorption. Perforation of the buccal and lingual cortical bone is highlighted.

In this situation, the crown may be turned toward the buccal or lingual sides, yet in contact with the oral environment, its microbiota and food debris (Figs 5 and 6). The chance of alternate episodes of acute and chronic pericoronitis giving rise to paradental cyst increases considerably on its distal aspect in this situation.[2]

5. Partially erupted and impacted on the second molars, with Inflammatory external root resorption due to the pericoronal follicular tissues in contact and interacting with the gingival and ligament tissues (Fig 9).[5,6] There will be compression of vessels, eliminating the cementoblasts from the root surface and initiating an inflammatory external root resorption on the distal surface of lower (Fig 10) and upper second molars (Fig 11).

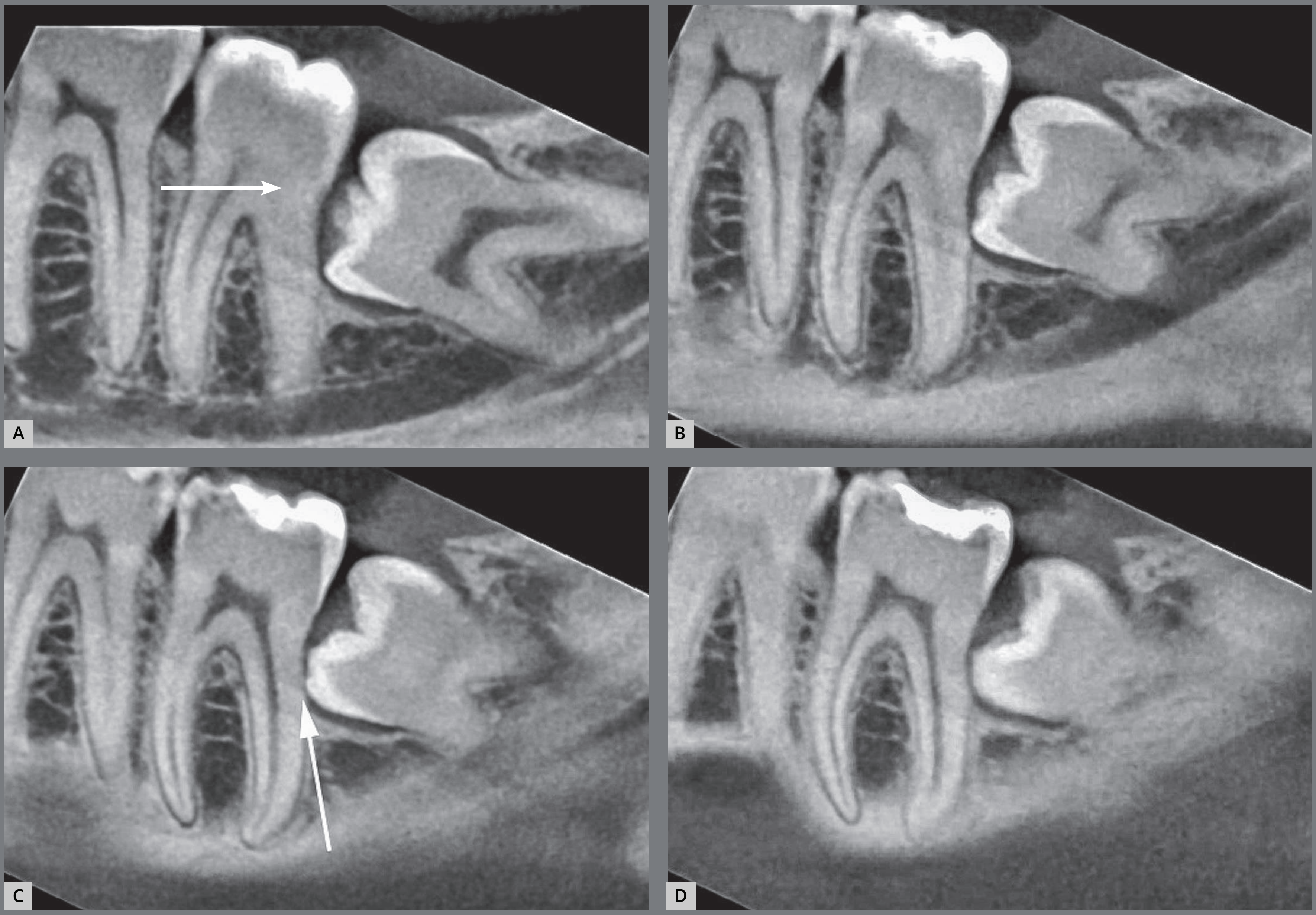

Figure 9: Incipient external inflammatory resorption on sagittal tomographic images. The partially erupted third molar with its pericoronal follicular tissues, combined to the force of the eruption pathway, can compress the vessels due to lack of oxygenation and eliminate the cementoblasts on the root of the associated lower second molars, thus initiating an external inflammatory resorption process (arrows).

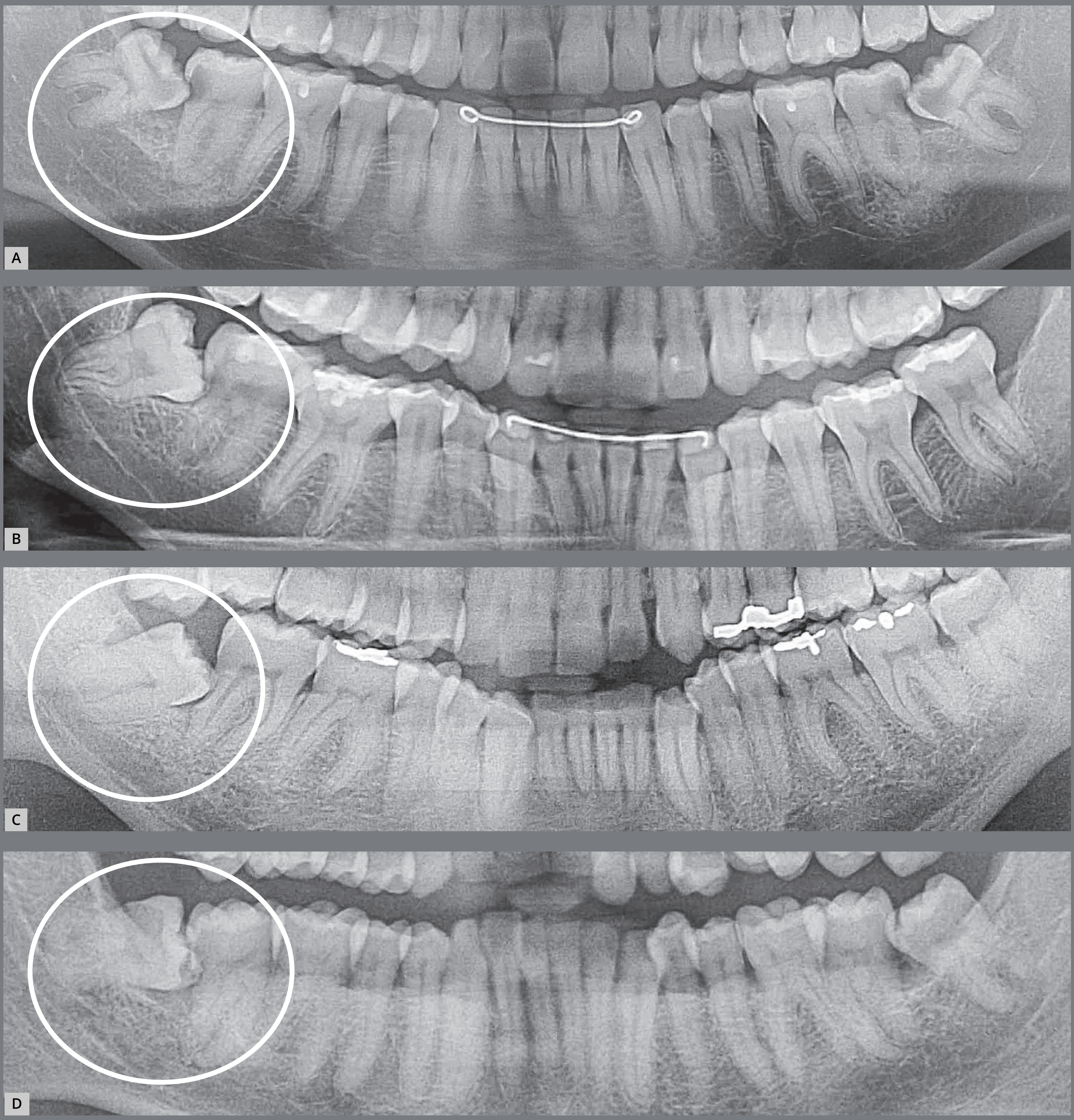

Figure 10: External inflammatory resorption on the distal surface of roots of the right lower second molars by direct action of the pericoronal follicular tissues of the lower third molars that compressed the vessels and led to death of cementoblasts. This resorptive process can be accelerated by the inflammation associated with the entry of bacteria via the distal gingival sulcus of the second molar and by partial exposure of the crown in the oral environment (arrow). Two patients (**A** and **B**) who were discharged from orthodontic treatment are highlighted.

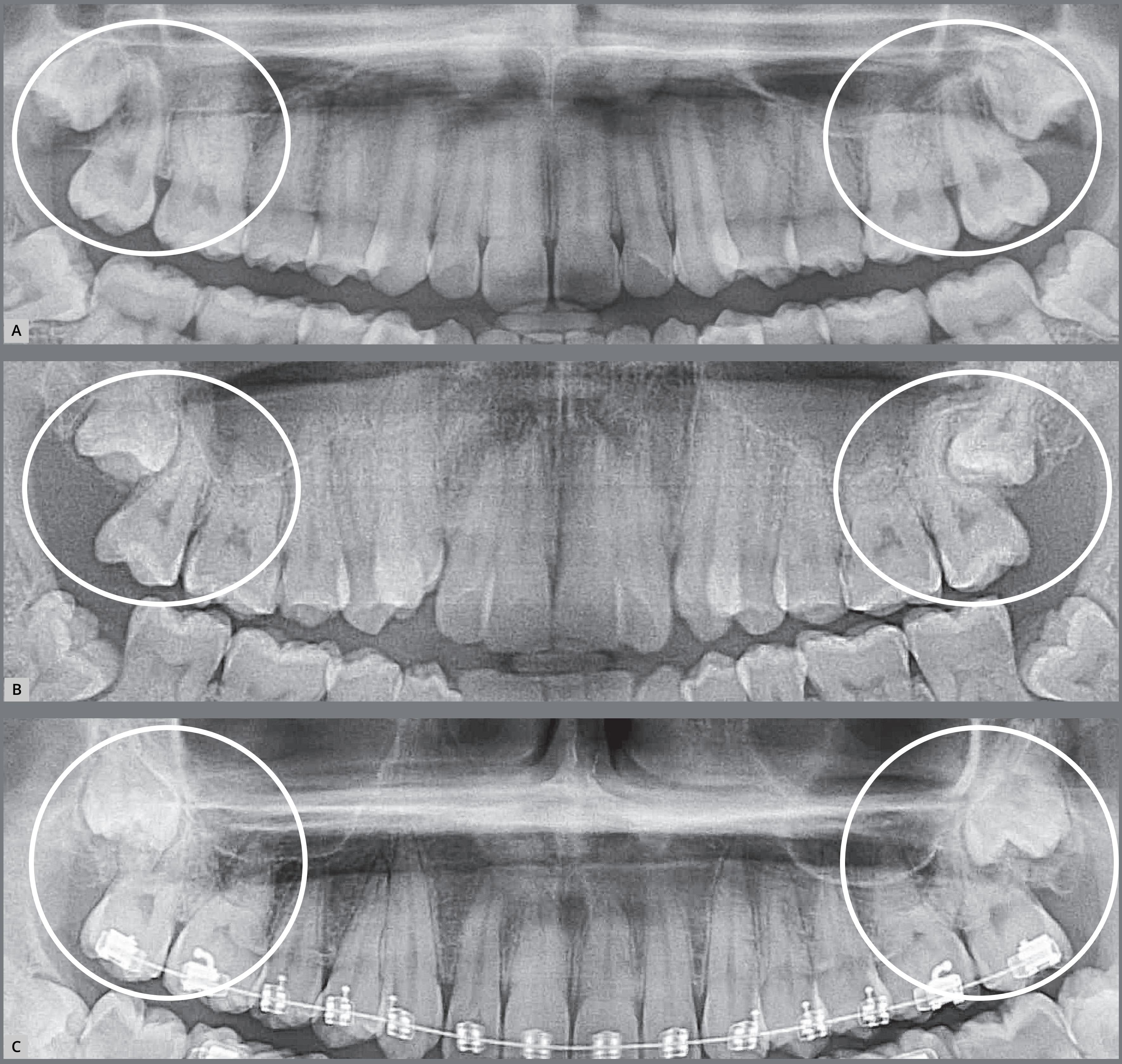

Figure 11: External inflammatory resorption on the distal surface of roots of the right and left upper second molars, by direct action of the pericoronal follicular tissues of the upper third molars. This resorptive process can be accelerated by the inflammation associated with the entry of bacteria through the distal gingival sulcus of the second molar and by partial exposure of the crown in the oral environment (arrow). The patient undergoing orthodontic treatment is highlighted in **C**.

6. Partially erupted, mesially angulated and impacted on the second molars, with inflammatory external cervical resorption from the cementoenamel junction of these teeth (Fig 12). The pericoronal follicles and associated inflammation digest the extracellular connective tissue matrix that hid the dentin in exposed micro-windows. The exposed dentin tends to be resorbed because it stimulates the immune system, since it has six proteins recognized as foreign by our body.[5,6]

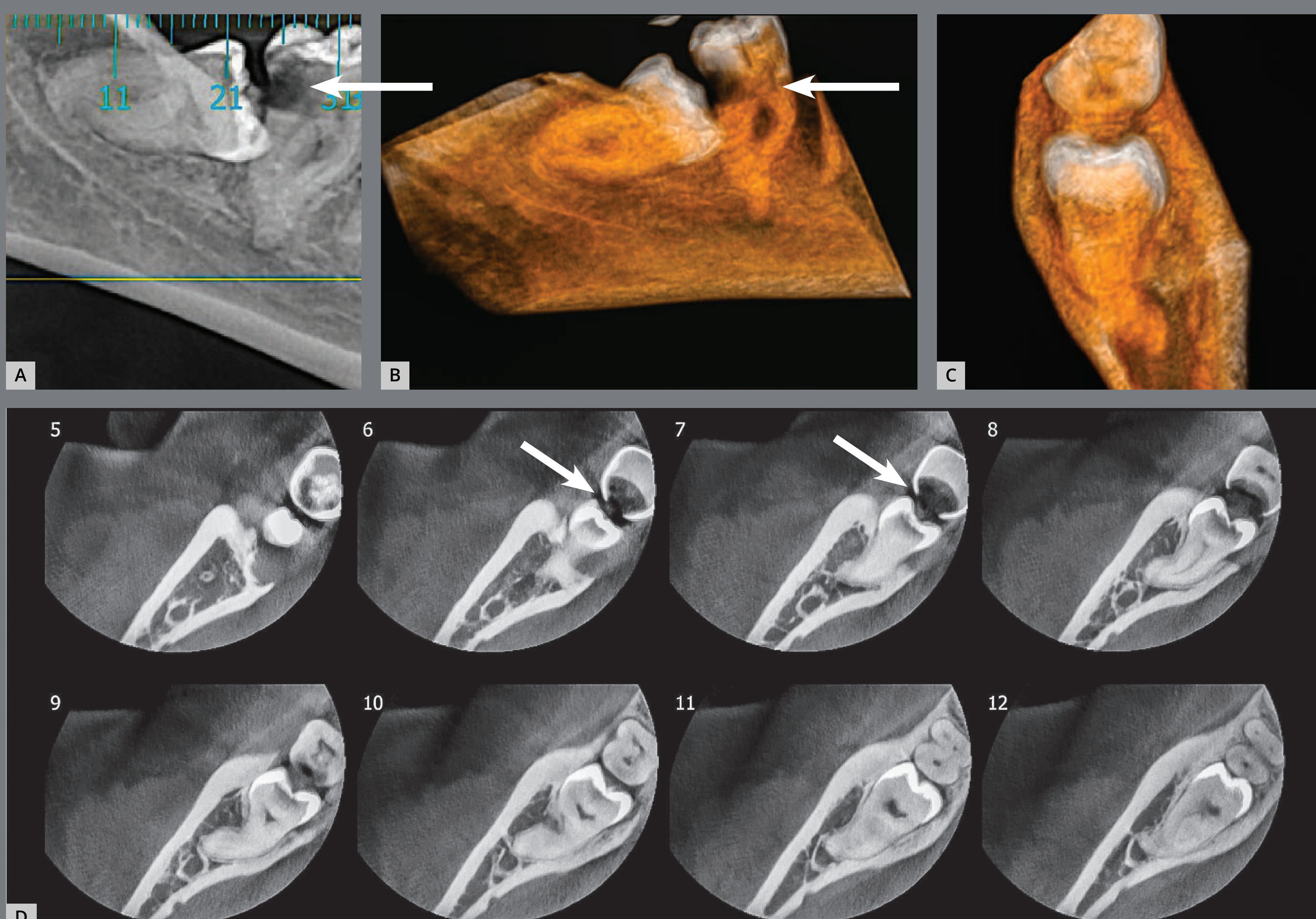

Figure 12: External cervical resorption in the second molar associated with exposure of the cementoenamel junction to follicular tissues of the partially erupted third molar (3D reconstruction in **B** and **C** and coronal sections in **D**).

7. Unerupted, without impaction on neighboring teeth, which occurs due to lack of bone space in the alveolar process. They are asymptomatic and are not even noticed by the patient, but due to their position they end up impacting the second molars over time or remain indefinitely unerupted.

Without a minimum masticatory function, the periodontal ligament becomes markedly atrophic over time and the teeth may eventually become ankylosed and undergo replacement tooth resorption, disappearing completely.[5,8,9]

In some occasional cases, the lack of eruption and without impaction, especially in upper third molars, the excessive proximity to the periodontal ligaments, being one of them without minimum masticatory function, can lead to concrescence[10] with the second molar (Fig 13).

8. Unerupted without impaction on neighboring teeth, with dentigerous cyst. This situation is occasional and occurs due to accumulation of fluid between the reduced enamel epithelium and the dental enamel (Fig 14). Supposedly the dentigerous cyst occurs due to venous compression in the eruptive movement, yet this is still only a theory to explain its mechanism of formation. The edema would lead to liquid accumulation between both structures. The dentigerous cyst is typical of dental development, while the paradental cyst is inflammatory

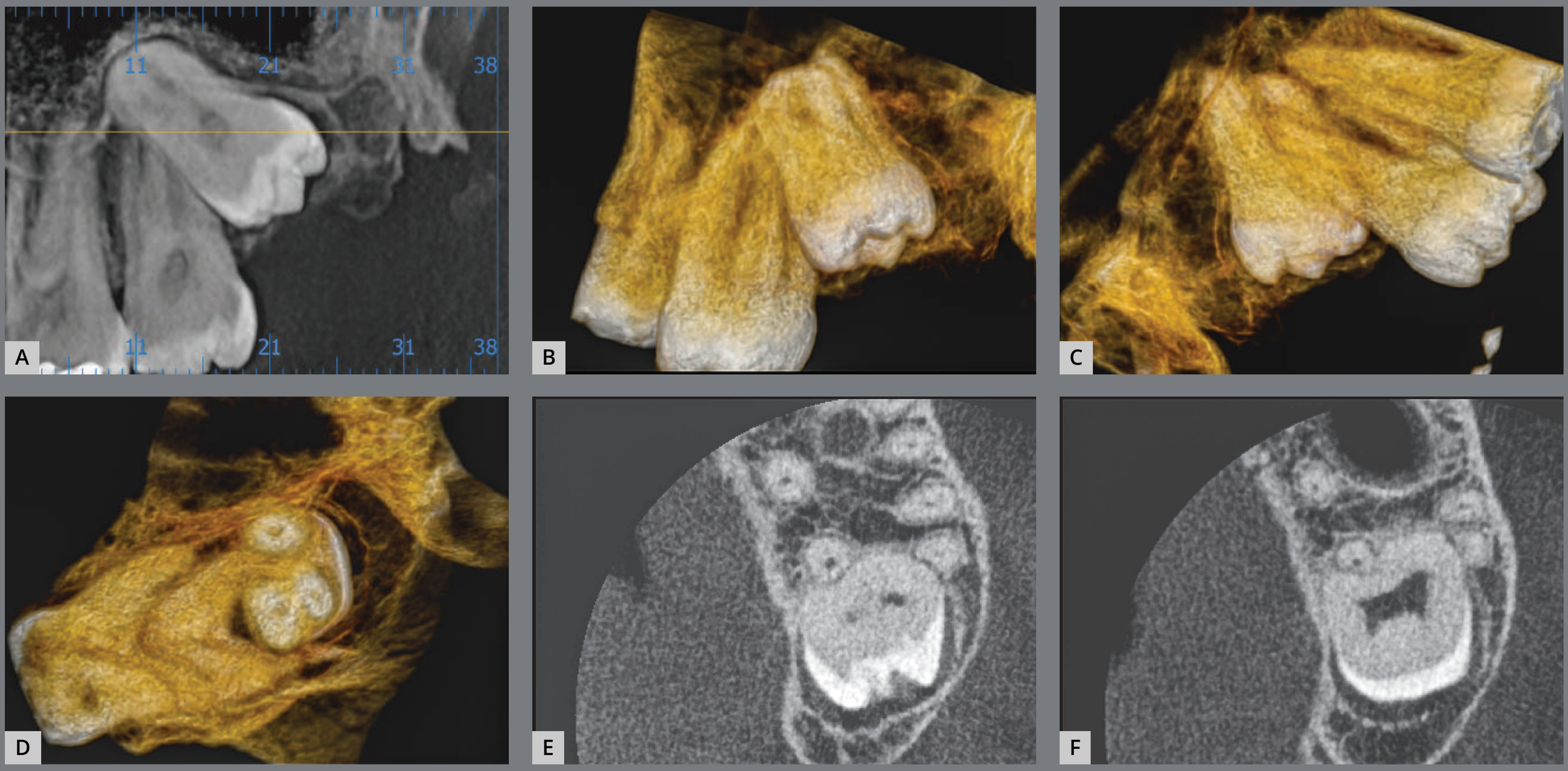

Figure 13: Concrescence of the upper third molar with the second molar on panoramic (**A**), axial (**E** and **F**) and 3D (**B**, **C** and **D**) tomography reconstructions, with buccal/palatal and axial views.

induced by previous acute and chronic pericoronaritis, i.e., it has another mechanism of formation.[3,4,6]

The pericoronal follicle has a thickness of up to 5.6 mm; above this, it should be considered a dentigerous cyst. Due to image distortion, this measure can make the case in a borderline situation. The greater the thickness of the follicular space, the more likely it is to be a dentigerous cyst. This situation is defined by the outflow of liquid between the follicle and enamel during transoperative surgical procedures. In these cases, it is also microscopically difficult to distinguish a pericoronal follicle from a dentigerous cyst.[1,2,3,4,6]

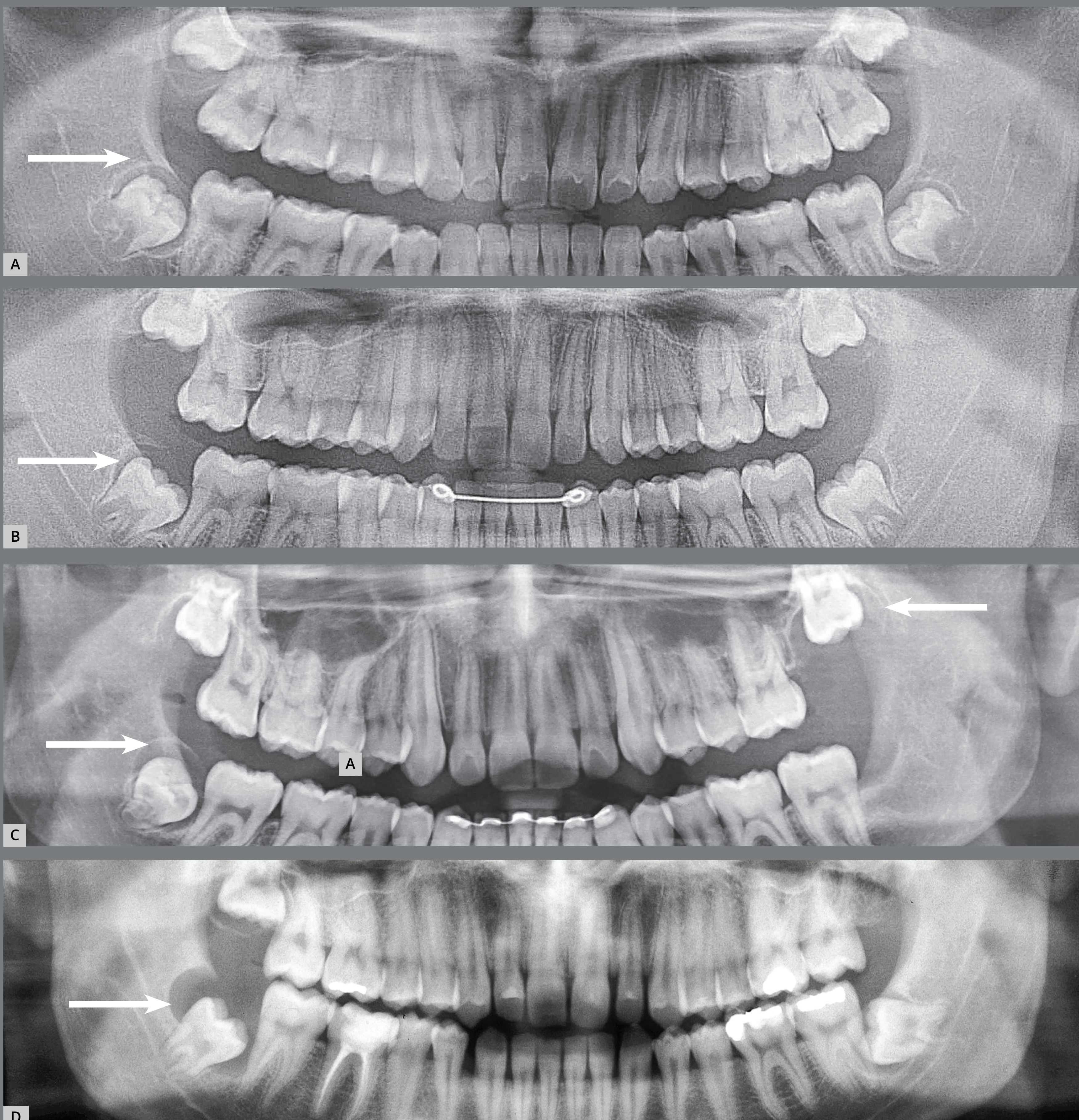

Figure 14: Dentigerous cysts: from normal pericoronal space to a gradual increase in thickness, causing the cystic cavity (arrows) by a process resulting from the eruptive process without microbial contamination, collecting liquid between the pericoronal follicular epithelium and enamel, without inflammatory process. In **B**, the patient who was discharged from orthodontic treatment is highlighted.

9. **Unerupted, without impaction on neighboring teeth, with odontogenic keratocyst.** Up to 30 years of age, the pericoronal follicle is rich in odontogenic epithelium islets derived from the dental lamina, which can give rise to odontogenic keratocyst. When developing in the pericoronal follicle, the odontogenic keratocyst will present the imaging and clinical aspect of dentigerous cyst for a long time (Fig 15). In most cases, the microscopic diagnosis of odontogenic keratocyst surprises the clinician and radiologist when receiving the histopathological report.[1,2,3,4,6]

10. Unerupted, without impaction on neighboring teeth, with ameloblastoma. The odontogenic epithelium islets may also eventually give rise to odontogenic tumors of the most varied types, including odontomas, ameloblastomas and other less common (Fig 15). This possibility is very small considering that there are many people with unerupted teeth, and the cases are occasional. It is so small that unerupted teeth may be followed with imaging examinations, in positions that would require major surgery on the mandibular ramus, orbit floor and mandibular base; or in cases of unerupted teeth in patients with systemic diseases as diabetes, autoimmune disorders, elderly individuals and other situations.

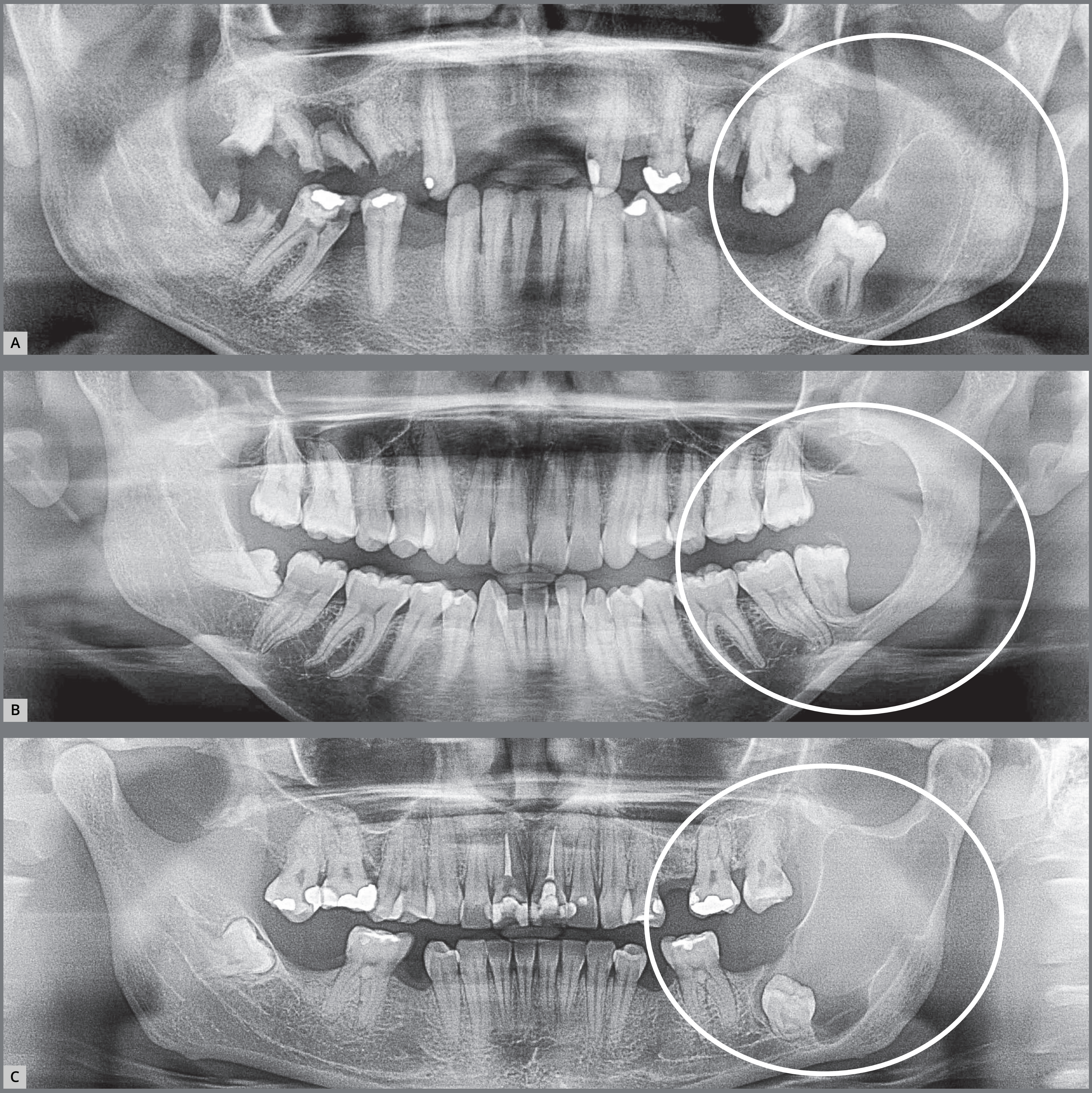

Figure 15: Odontogenic keratocysts that mimic the dentigerous cyst and even ameloblastoma, originated from dental lamina rests of the pericoronal follicle. The odontogenic keratocyst occurs is the posterior region of the mandible, especially associated with the third molars.

After 30 years of age, the odontogenic islets and epithelia undergo atrophy and then apoptosis, decreasing the possibility of odontogenic cysts and tumors starting after this stage of life[3]. Sometimes the possibility of an unerupted tooth giving rise to an odontogenic tumor such as ameloblastoma is greatly reinforced because of an inverted analysis of the problem: half of cases of odontogenic tumor are associated with unerupted teeth! Either because they give rise to them or because they prevent their eruption, but even so the number of cases in the population is very small, considering the number of teeth and the number of people, so that it is not possible to speak in percentage, since it would be extremely small in number.

FINAL CONSIDERATIONS

A dental patient should not be discharged without being sure that he or she does not have a disease in the jaws. For this reason, in any planning, even for a simple restoration, it is important to have panoramic and periapical radiographs of the jaws in hands.

Unfortunately, many patients finish their treatments and are discharged by the professional, yet the third molars present anomalies of position or eruption, inducing resorptions in neighboring teeth, with pericoronitis and paradental cysts, besides neoplasms.

Working on dental crowns requires knowledge on how the periodontium and underlying bone are, always thinking about the patient as a whole also over time. The diseases, even the most serious, start small and with asymptomatic signs. The early diagnosis can prevent further damage and functional and structural mutilation.

AUTHORS' CONTRIBUTION

Alberto Consolaro (AC)

Omar Hadaya (OH)

Conception or design of the study; Data acquisition, analysis or interpretation; Writing the article; Critical revision of the article; Overall responsibility: AC, OH.

Patients displayed in this article previously approved the use of their facial and intraoral photographs.
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REFERENCES

1. Rendón ACT. Estudo comparativo do cisto folicular inflamatório com o cisto dentígero e folículo pericoronário: aspectos microscópicos e implicações etiopatogênicas [dissertação]. Bauru (SP): Universidade de São Paulo - Faculdade de Odontologia de Bauru: 2002.
2. Velloso TRG. Cisto paradentário, pericoronarite crônica e folículo pericoronário de dente parcialmente irrompido: análise morfológica comparativa e correlações clínico- radiográficas [tese]. Bauru (SP): Universidade de São Paulo - Faculdade de Odontologia de Bauru: 2004.
3. Consolaro A. Caracterização microscópica de folículos pericoronários de dentes não irrompidos e parcialmente irrompidos: sua relação com a idade [tese]. Bauru (SP): Universidade de São Paulo - Faculdade de Odontologia de Bauru: 1987.
4. Damante JH. Estudo dos folículos pericoronários de dentes não irrompidos e parcialmente irrompidos: inter-relações clínicas, radiográficas e microscópicas [tese] Bauru (SP): Universidade de São Paulo - Faculdade de Odontologia de Bauru: 1987.
5. Consolaro A. Reabsorções dentárias nas especialidades clínicas. 3ª ed. Maringá: Dental Press; 2012.

6. Consolaro A, Hadaya O, Cardoso MA. Reasons for removing unerupted or partially erupted third molars. Clin Orthod. 2020 Aug-Sept;19(4):153-60.
7. Consolaro A. External cervical resorption: diagnostic and treatment tips. Dental Press J Orthod. 2016 Sept-Oct;21(5):29-35.
8. Consolaro A, Ribeiro Júnior PD, Cardoso MA, Miranda DAO, Salfatis M. Decoronation followed by dental implants placement: fundamentals, applications and explanations. Dental Press J Orthod, 2018 Jan-Feb;23(1):24-36.
9. Consolaro A, Hadaya O, Consolaro RB, Miranda DAO. Ankylosis and replacement resorption of enamel in unerupted teeth. Clin Orthod. 2020 Dez-2021 Jan;19(6):126-32.
10. Consolaro A, Furquim LZ, Hadaya O, Roldi A, Miranda DAO, Consolaro RB. Dentes unidos por planejamento ortodôntico: geminação, fusão e concrescência. Rev Clín Ortod Dental Press. 2019 Dez-2020 Jan;18(6):114-26.

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ORIGINAL ARTICLE

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An eye-tracking and visual analogue scale attractiveness evaluation of black space between the maxillary central incisors

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ABSTRACT

Objective: To study the influence of black space between the maxillary central incisors on the aesthetic visual perception of the face, via eye-tracking and visual analogue scale (VAS).

Methods: Black space between the central incisors was created, for both sexes, as follows: control, 1-mm black space, 2-mm black space and 3-mm black space. Ninety raters participated in this study, divided into three groups: 30 laypeople, 30 nonorthodontists, and 30 orthodontists. After the visual calibration of each observer, eight photographs were presented in the Ogama® software concomitant with the use of the hardware The Eye Tribe®. Ogama generated information depending on the eye-tracking of each rater, regarding the time until the first fixation, time of fixation, heatmap, scanpath, and total time of fixation, to evaluate the areas deemed to be of interest according to the raters. Later on, the VAS was used, where each rater evaluated the images in an album on a scale of zero to 10 points.

Results: The eyes and mouth were the areas more often noticed by the raters according to the heatmaps, while no significant difference was observed in time until the first fixation between the three groups of raters ($p > 0.05$). However, regarding the time of fixation on the mouth, a significant difference was observed ($p < 0.05$) when comparing the three groups.

Conclusion: Black space has a negative effect on the aesthetic perception of the face. The amount of attention on the mouth is correspondent to the size of the black space.

Keywords: Black space. Perception. Esthetics. Eye-tracking.

RESUMO

Objetivo: Avaliar a percepção visual e estética do espaço negro entre os incisivos centrais superiores, via rastreamento do olhar e escala visual analógica (EVA).

Métodos: Manipulou-se o espaço negro entre os incisivos centrais superiores, para ambos os sexos, da seguinte forma: imagem controle, espaço negro de 1 mm, espaço negro de 2 mm e espaço negro de 3 mm. Participaram desse estudo noventa avaliadores, divididos em três grupos: 30 leigos, 30 cirurgiões-dentistas e 30 ortodontistas. Após a calibração visual de cada observador, foram projetadas oito fotografias no *software* OGAMA® em conjunto com o *hardware* The Eye Tribe®. O OGAMA gerou informações do rastreamento do olhar de cada avaliador com relação ao tempo até a primeira fixação, mapa de calor, trajetória do olhar e tempo total de fixação para avaliar as áreas consideradas de interesse, de acordo com os avaliadores. Posteriormente, utilizou-se a EVA para avaliar as imagens a partir de um álbum, em uma escala de 0 a 10 pontos.

Resultados: Os olhos e a boca foram as áreas com maior fixação pelos avaliadores, de acordo com os mapas de calor. Os resultados estatísticos não apresentaram diferença estatisticamente significativa entre os três grupos de avaliadores ($p > 0,05$), quanto ao tempo até a primeira fixação. Porém, em relação ao tempo de fixação na boca, observou-se diferença estatisticamente significativa ($p < 0,05$) na comparação dos três grupos.

Conclusão: O espaço negro apresentou um efeito negativo na percepção estética da face. O aumento de fixação na boca correspondeu ao aumento do tamanho do espaço negro.

Palavras-chave: Espaço negro. Percepção. Estética. Rastreamento do olhar.

INTRODUCTION

Orthodontic treatment is focused on enhancing the facial aesthetics, function, and general appearance. Importantly, even the smallest details can affect the smile attractiveness.

Both the smile and facial attractiveness constitute important aesthetic and social factors,[1] because attractiveness increases the social interactions and develops the personality.[1,2] The seek for facial perfection augments the necessity of studying aesthetic perceptions, and the use of digital programs helps to achieve more satisfactory results for patients.[3,4] In health sciences, the construction of the values and meaning of the corporal aesthetic is receiving increased interest, influencing individual's identity construction and self-perception.[5]

Knowledge of the patient's psychological, anatomical, and functional needs can lead to better detection of changes or defects that may alter the aesthetic perceptions of the smile and identify the existing problems, in order to improve the aesthetic outcomes of orthodontic treatment and increase the quality of life of the patients.[5,6]

Aesthetic perception is related to educational, cultural, socioeconomical and emotional contexts. Importantly, studies have shown that perception differs between orthodontists, nonorthodontists (i.e., dentists), and laypeople.[7]

Eye-tracking has been used in visual perception investigations for a long time.[8] The technique has been continuously refined since the introduction of the first eye-tracking machine.[9]

Black space is also known by the terms "black triangle" or "gap" and can be the result of: inclination of the maxillary central incisors in the mesial or distal direction; bone loss; triangular formation of the maxillary central incisors; or lesions associated with plaque, trauma, or tooth loss.[9-11] The existence of these spaces can alter the smile aesthetic, although the degree of impact depends on the self-evaluation of the patient.[9,11]

A study demonstrated that in 98% of cases the interdental papilla is considered complete when the distance between the alveolar crest and the area of contact between the maxillary central incisors is equal to or less than 5 mm. With a distance of 6 mm, the papilla is considered complete in 56% of cases and this number decreases in the case of a 7-mm distance (27% of the cases).[12]

Previous studies with an objective of establishing a relation between the black space and smile attractiveness have confirmed that the black space has a negative repercussion on the dental aesthetic.[13] In addition, young people are more capable of detecting the black space, ranking the smile as less attractive when greater black space is present.[7]

Eye-tracking is a trusted technique used to study aesthetic visual perception.[14] Attractive judgment using a visual analogue scale (VAS) is also a simple and objective method for evaluating aesthetic perceptions and for helping to compare results between groups of raters.[15]

Therefore, the aim of the present study was to evaluate the effects of different sizes and magnitudes of black space between the maxillary central incisors in both sexes, with regard to aesthetic perception, by using an attractive assessment VAS and eye-tracking technique.

MATERIAL AND METHODS

This study was approved by the Committee of Human Ethics and Research of *Pontifícia Universidade Católica do Paraná* (# 2.235.302). Photos of individuals of both sexes were used, excluding those with characteristics that alter the visual attention such as beards, tattoos, exaggerated makeup or exotic hairstyles.

Facial and intraoral photographs were obtained using a Canon XT camera (Canon Inc., Tokyo, Japan), 50mm Sigma macro lens and Sigma flash. All photographs were obtained in a proper studio, with a white background.

High-resolution photographs were selected by three experienced orthodontists. The aspects of normality regarding symmetry, volume and color were observed. The images were edited in the Photoshop CS5® software (Adobe Inc., San Jose, CA, USA) by an experienced professional.

Subsequently, the individuals' actual smiles were excluded and another smile with better occlusion was inserted, to reduce the bias of the visual attention, because the original smiles were not symmetrical and the malocclusion could alter the visual attention and reduce the aesthetic perception. The aim of this study was to evaluate only the impact of the black spaces and its effect on the aesthetic perception.[14] The black space was copied from a real photograph of a patient with black space, and then readapted to the study images.[13] Black space between the central incisors was created, for both sexes, as follows:, Control, 1-mm black space, 2-mm black space and 3-mm black space (Fig 1).

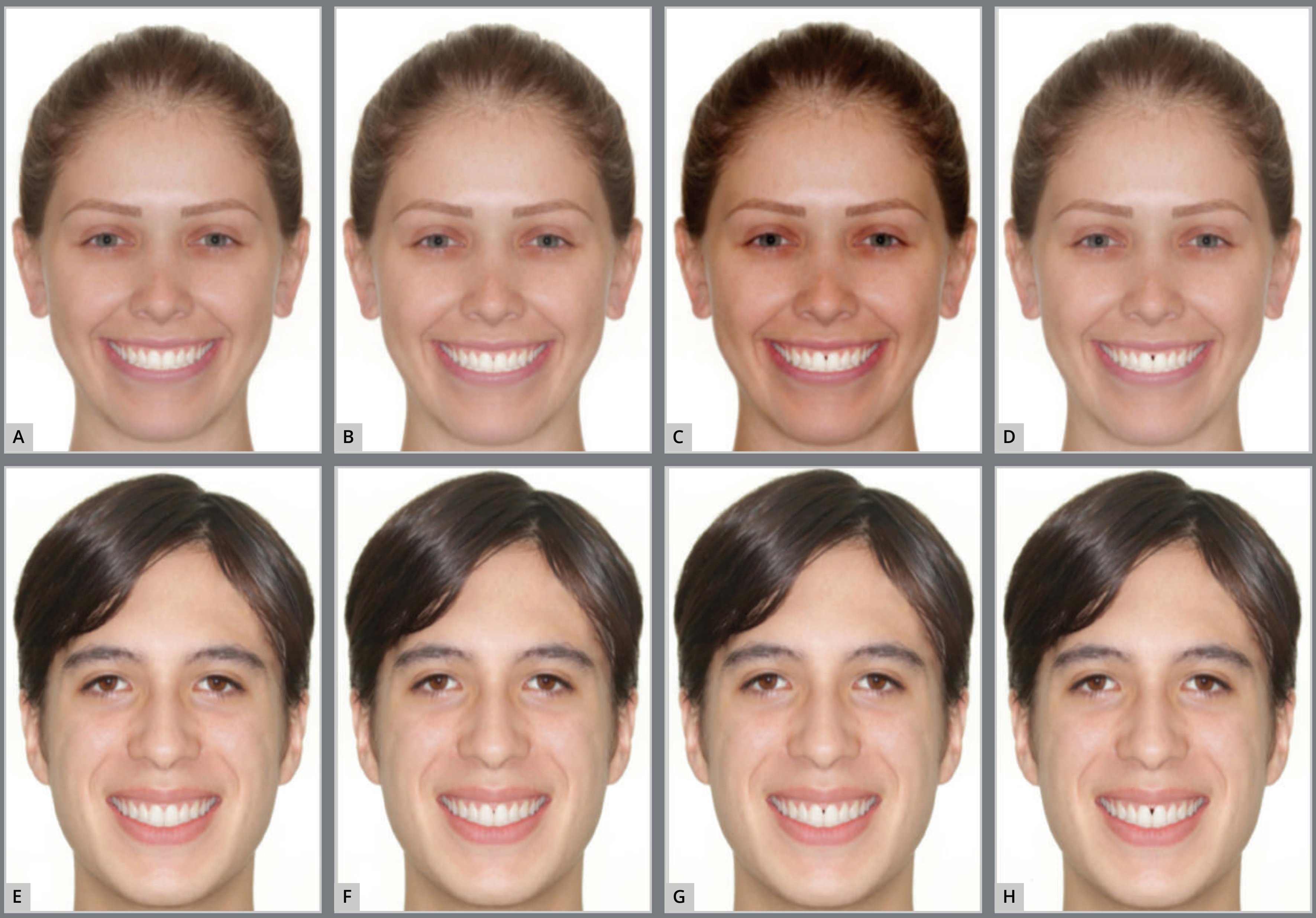

Figure 1: Black space on female patient: **A)** no black space; **B)** 1 mm, **C)** 2 mm, **D)** 3 mm. Black space on male patient: **E)** no black space; **F)** 1 mm, **G)** 2 mm, **H)** 3 mm.

The Ogama software (Freie Universität, Berlin, Germany) was used to perform eye-tracking, along with the The Eye Tribe tracking device. The Ogama software (OpenGazeAndMouseAnalyzer) was created and used to record and analyze eye movements based on multiple slide stimuli. This software provides qualitative (heatmap and scanpath) and quantitative analysis (total time of fixation in milliseconds and relative transition value that explains the scanpath) findings. All images were randomly included in the software in accordance with guidelines generated by the website www.randomizer.org, as follows: 2-mm black space, female; 3-mm black space, female; 1-mm black space, female; 2-mm black space, male; and 1-mm black space, male; control black space, male; control black space, female; and 3-mm black space, male. Each included image was adjusted to be visualized for three seconds by the raters and separated by a slide with white and green colors for one second, so that the last point of fixation of the previous image did not interfere with the first fixation point of the next one.

Areas of interest (AOIs) in all images were also delimited by the Ogama software to obtain more accurate information about eye-tracking, as well as to make comparisons (Fig 2). The time to the first fixation (ms), fixation number, heatmap and scanpath of each evaluator were obtained for each AOI. All of the first fixations were eliminated as well as were the fixations with durations of less than 200 ms.

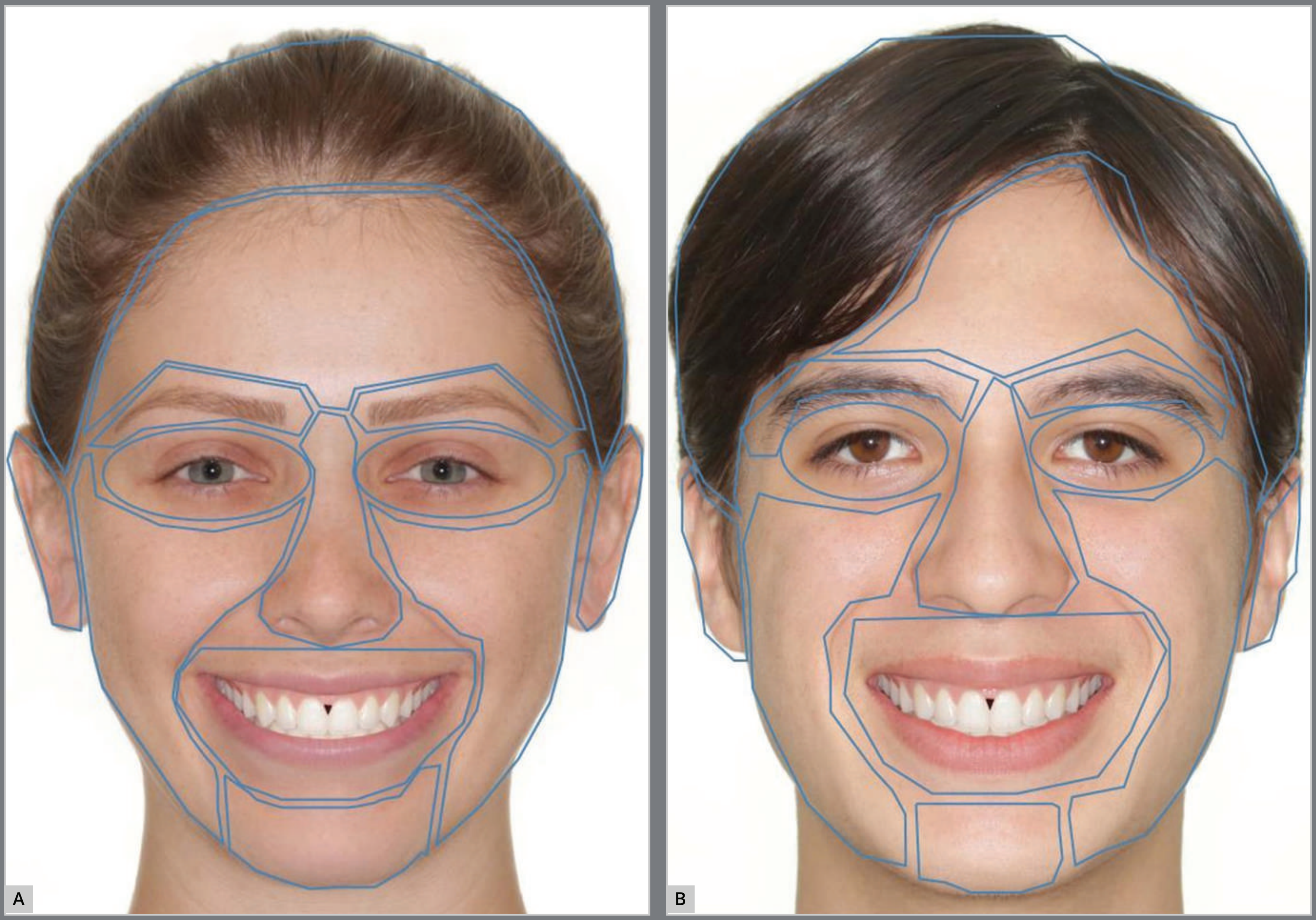

Figure 2: Delimited areas of interest of female and male faces.

The distance used between the participant and The Eye Tribe hardware was 60 cm to 90 cm, as recommended by the manufacturer; and the height of the viewer's chair was customized to capture the eyes in the center of a 23-inch monitor (Dell P2317H; Dell, Round Rock, TX, USA) positioned vertically. To begin the eye-tracking test, a standard eye movement calibration was performed and only excellent or good results were considered;

the test was repeated when the result was poor or redo-commanded. When the test showed a poor or redo result twice, the participant was excluded from the study.

The raters were divided into three categories with 30 individuals each (layperson, nonorthodontist, and orthodontist). The following inclusion criteria were used: no previous neurological and/or vision impairment conditions; no recent use of drugs, alcohol, or medications that could interfere with cognitive abilities; Caucasian (to prevent bias due to race and/or nationality); and good eyesight (the use of glasses could interfere with the sensor). All volunteers were informed of the research conditions, risks and benefits, and signed a consent form.

After eye-tracking test, the same images were presented printed and organized in the same order, so that the raters could assess the attractiveness according to the VAS from zero to 10 points, with closer to zero points being less attractive, and closer to 10 points being more attractive.

STATISTICAL ANALYSIS

The obtained results from eye-tracking and VAS were tabulated in the Microsoft Excel software (Microsoft Corp., Redmond, WA, USA) and analyzed in the Statistical Package for the Social Sciences software version 25 (IBM Corp., Armonk, NY, USA).

An analysis of variance (ANOVA) was used to demonstrate differences, comparing the mean values of the number of fixations and time to first fixation of the different groups of raters, as well as for VAS and each variable of the areas of interest (e.g., eyes, eyebrows, nose, mouth, forehead, hair, ears, and cheeks) with respect to the observer and the deviation (black space and diastema). For the independent sex variable, the Student's *t*-test was used for independent samples. When the variables were continuous, to assess if there was an association between the two variables, the Pearson correlation coefficient was used.

When ANOVA indicated a statistically significant difference and the Levene homogeneity test indicated homogeneous variances, a two-way comparison was made, using Tukey's multiple parametric comparison test for homogeneous variances. Otherwise the two-to-two comparison was made, using Games–Howell's multiparametric comparison test for heterogeneous variances.

From the sample size of n = 30 or n > 30, considering the VAS variable for each category of the black space using SPSS software, the ANOVA method was applied to verify differences between observers and, in each dependent variable, was calculated the power of the test (observed power) for all cases in that there was a statistically significant difference. In none of the situations the power of the test was below 70%, and in most cases it was above 90%.

To correlate the mean values of the values assigned to the images with the VAS and the variables captured by the eye-tracking, the Pearson correlation test was used.

The final sample number of the survey among laypeople, non-orthodontists and orthodontists was 90, or 30 in each group. The age range of the raters was 18 to 46 years, with a mean age of 32 years. Regarding the sex of the participants, 52% (n = 47) were female and 48% were male (n = 43).

RESULTS

The results of the eye-tracking showed that the mouth, right eye, and left eye were the most captured areas.

In relation to the time to first fixation and number of fixations of the mouth, dentists and orthodontists presented lower values than laypeople ($p > 0.05$) and there was no difference between nonorthodontists and orthodontists ($p > 0.05$) (Tables 1 and 2).

In relation to attractive judgment based on the VAS, it was observed that the aesthetic perception decreased as the magnitude of the black space increased and that the highest notes were given for the images without any smile problems (Table 3).

A statistically significant difference ($p < 0.05$) was found when comparing the VAS outcomes between groups of raters. In the multicomparison of the values of the visual analogue scale, there was a statistically significant difference between the images of the female individuals without black space *versus* the images with black spaces of 1, 2, and 3 mm ($p < 0.05$).

Regarding the results of the heatmaps, it was shown that laypeople looked more to the eyes, in comparison to nonorthodontists and orthodontists, while the concentration of the gaze on the mouth increased as black spaces of 1, 2, and 3 mm appeared (Figs 3 and 4).

For nonorthodontists and orthodontists, the heatmaps demonstrated that the concentration on the mouth was greater than for laypeople, regardless of the magnification of black spaces in both sexes, mainly for orthodontists (Figs 3 and 4).

The scanpaths and the heatmaps revealed that the rater eye focus was correspondent to the size of the black space, especially for orthodontists. Upon evaluating the scanpaths of the control images, the eyes and the mouth were deemed to be the regions with greater focus.

Table 1: Comparison of variations between all raters.

	Visual analogue scale	Time (ms) to first fixation (right eye)	Time (ms) to first fixation (mouth)	Number of fixations (right eye)	Number of fixations (mouth)
p value between groups	0.002	0.904	0.004	0.132	0.001

Table 2: Comparison between the three groups, by pairs.

	Visual analogue scale	Time (ms) to first fixation (right eye)	Time (ms) to first fixation (mouth)	Number of fixations (right eye)	Number of fixations (mouth)
Dentist x Orthodontist	0.316	0.915	0.904	0.109	0.065
Layperson x Dentist	0.128	0.915	0.007	0.441	0.441
Layperson x Orthodontist	0.001	1.000	0.015	0.627	0.001

Table 3: Mean and standard deviation of the evaluations, based on the visual analogue scale (VAS) between the different groups of raters.

VAS X GROUPS	Layperson	Nonorthodontist	Orthodontist	*p* value
	Mean (SD)			
1-mm black space female	6.1875 (2.10)	6.625 (2.01)	5.8 (1.88)	0.373
2-mm black space female	5.4688 (2.16)	4.9688 (2.65)	3.9 (2.07)	0.542
3-mm black space female	4.8125 (2.44)	4.375 (2.61)	3.8 (1.99)	0.695
Control female	8.125 (2.01)	8.4063 (1.47)	8.675 (1.54)	0.389
1-mm black space male	6.28 (2.53)[a]	5.75 (2.74)[b]	5.45 (1.97)[b]	0.001
2-mm black space male	4.4688 (2.46)	4.2188 (2.45)	3.025 (2.12)	0.116
3-mm black space male	3.5938 (2.35)	3.3125 (2.29)	2.175 (2.22)	0.407
Control male	6.5313 (2.79)[a]	7.5313 (2.69)[a]	8.75 (1.29)[b]	0.000

Different superscript letters indicate a statistically significant difference; statistically significant at $P<0.05$.
VAS = Visual Analogue Scale. SD = Standard Deviation.

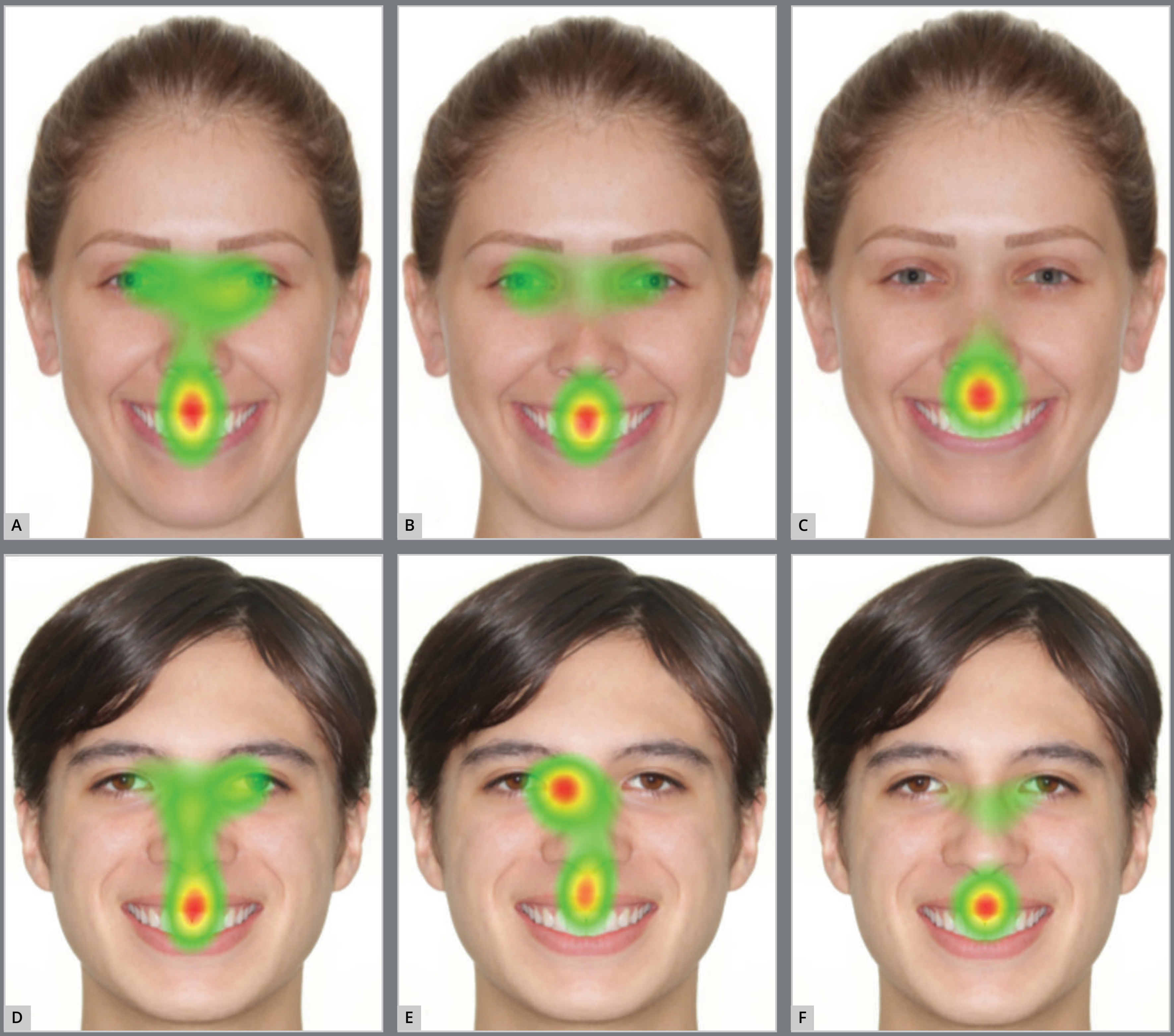

Figure 3: Heatmaps of the images of female patient with black space of 1mm: **A)** Laypeople, **B)** nonorthodontists and **C)** orthodontists. Heatmaps of the images of male patient with black space of 1mm: **D)** Laypeople; **E)** nonorthodontists and **F)** orthodontists.

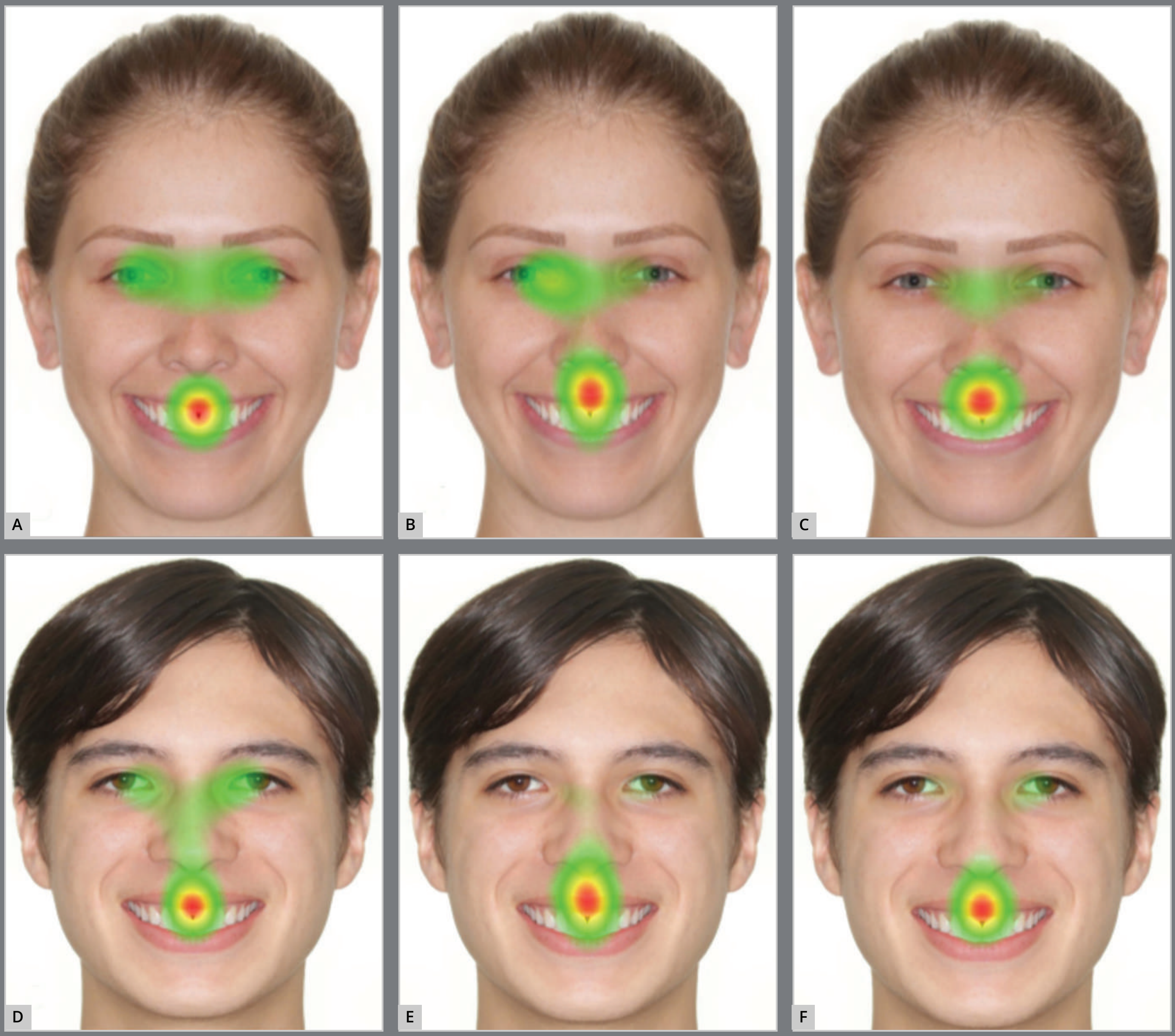

Figure 4: Heatmaps of the images of female patient with black space of 3mm: **A)** Laypeople, **B)** nonorthodontists and **C)** orthodontists. Heatmaps of the images of male patient with black space of 3mm: **D)** Laypeople; **E)** nonorthodontists and **F)** orthodontists.

DISCUSSION

This study verified, by means of eye-tracking and visual analogue scale (VAS), the influence of black space on the general perception of face aesthetics evaluated by laypeople, nonorthodontists and orthodontists. It was verified that there is a negative effect of black space on general aesthetic perception of the face and smile.

Other studies of aesthetic perception have compared these groups of individuals.[16,17] The results confirmed that all groups evaluated negatively the images of 3-mm black space in both sexes and that the orthodontists were the most critical observers. However, the three rater groups also demonstrated a negative perception of black space of 1 mm and 2 mm.

The mouth or the lower third of the face was used in most prior studies of aesthetic perception. The study by Dindaroglu et al.[20] used a cropped area of the face between the eyes and chin, without ears or hair. In the present study, images of the full face of both sexes were used, considering that, in everyday social relations, individuals have a general visual of the face in conjunction with the smile, not only an isolated region.

In this study, with the two techniques, it was possible to observe lower scores, referring to the images with larger black spaces and the raters concentrated on the mouth region. This can be explained by the fact that the existence of black space reduces the aesthetic perception of the face. However, no correlation was observed between the values of the VAS and the variables analyzed by eye-tracking.

The heatmaps of the eye-tracking showed that the eyes and mouth were the most interesting areas for all groups, showing an aesthetic relationship between the eyes and the mouth. However, the concentration toward the mouth was increased as black spaces were inserted in the photographs, suggesting the worsening of the aesthetics, confirmed by the evaluations through the VAS. Other studies that used eye-tracking also observed the same pattern of visualization between the eyes and mouth, and an increased concentration on the mouth region when black spaces were added to the smile.[14,21]

Besides that, it was also demonstrated that, in relation to time to first fixation in the mouth, there was a statistically significant difference between laypeople and nonorthodontists and between laypeople and orthodontists. As the area of concern for these professionals is the mouth, it is natural that they looked faster to the smile. However, other studies using eye-tracking have confirmed that time to first fixation may not be a very reliable measure.[14,22,23]

In the present study, orthodontists showed a higher attention to the mouth in the presence or absence of black space, regardless of rater sex, and were also more critical in the evaluation through VAS. These results are in agreement with other studies of perception, in which orthodontists perceived defects of a smaller magnitude when compared to other groups of raters.[11,24,25] The present results can be expected then, since these professionals are trained to diagnose several types of occlusal abnormalities involving aesthetics and function.

A perfect smile has a positive repercussion on the dental aesthetics.[26]Comparing the three groups, it can be seen with the heatmaps and scanpaths that a black space of 3 mm shifts the concentration from the eyes to the mouth, neglecting the other areas of the face, in all three groups. This findings suggests the negative effect of black space on the smile for the perception of aesthetic attractiveness. The presence of black space of 1 mm and 2 mm also negatively influenced the aesthetic perception, when compared to the same image without a defect. Richards et al.[14] observed that unattractive smiles changed the attention of the observer's eyes on faces with different degrees of attractiveness; these results are in agreement with the present study, in which the perfect smile gained the highest scores among the three groups.

The results of this research correspond also with the research of Pithon et al.,[7] who showed that the presence of black space between the maxillary central incisors was an important factor to decrease the aesthetic attractiveness of the smile, and revealed that black space decreased the overall aesthetic attractiveness of the face.

Eliminating black space should be included in the dental treatment plan, to augment the aesthetic perception and patient's satisfaction. Nowadays, many dental aesthetic solutions can be applied depending on the case of each patient, as reported by Tanaka et al.[27]

A limitation of this study is that the test was applied only in one location, so the results reflect only the perceptions of one community, not a nationwide group.

CONCLUSION

Black space, in the magnitudes of 1, 2, and 3 mm, negatively affected the aesthetic perceptions of male and female faces in the evaluation of laypeople, nonorthodontists, and orthodontists.

Orthodontists showed greater attention on the mouth region in relation to the nonorthodontists and laypeople.

Analysis of the aesthetic perceptions among laypersons, non-orthodontists, and orthodontists, based on the VAS, found that orthodontists were the most critical.

The raters focused the eyes more than the mouth in both sexes in the control images. However for the images with 1mm of black space, the focus shifted to the mouth for the male patient. Separately, in images of 2 mm and 3 mm of black space, the concentration of the raters was on the mouth in both sexes.

AUTHORS' CONTRIBUTION

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Conception or design of the study:

AA, CSM, TMM, OMT.

Data acquisition, analysis or interpretation:

AA, PHCS, CSM, SAI, TMM, OMT.

Writing the article:

AA, PHCS, CSM, SAI, TMM, OMT.

Critical revision of the article:

AA, PHCS, CSM, SAI, TMM, OMT.

Final approval of the article:

AA, PHCS, CSM, SAI, TMM, OMT.

Fundraising:

OMT.

Overall responsibility:

OMT.

Patients displayed in this article previously approved the use of their facial and intraoral photographs.

The authors report no commercial, proprietary or financial interest in the products or companies described in this article.

REFERENCES

1. Van der Geld P, Oosterveld P, Van Heck G, Kuijpers-Jagtman AM. Smile attractiveness. Self-perception and influence on personality. Angle Orthod. 2007 Sept;77(5):759-65.
2. Langlois JH, Kalakanis L, Rubenstein AJ, Larson A, Hallam M, Smoot M. Maxims or myths of beauty? A meta-analytic and theoretical review. Psychol Bull. 2000 May;126(3):390-423.
3. Machado AW. 10 commandments of smile esthetics. Dental Press J Orthod. 2014 July-Aug;19(4):136-57.
4. Sodagar A, Rafatjoo R, Gholami Borujeni D, Noroozi H, Sarkhosh A. Software design for smile analysis. J Dent (Tehran). 2010 Fall;7(4):170-8.
5. Normando D. Esthetics and human perception. Dental Press J Orthod. 2012 Sept-Oct;17(5):1.
6. Shaw WC. Factors influencing the desire for orthodontic treatment. Eur J Orthod. 1981;3(3):151-62.
7. Pithon MM, Bastos GW, Miranda NS, Sampaio T, Ribeiro TP, do Nascimento LEAG, et al. Esthetic perception of black spaces between maxillary central incisors by different age groups. Am J Orthod Dentofacial Orthop. 2013 Mar;143(3):371-5.
8. Eckstein MK, Guerra-Carrillo B, Singley ATM, Bunge SA. Beyond eye gaze: what else can eyetracking reveal about cognition and cognitive development? Dev Cogn Neurosci. 2017 June;25:69-91.

9. Desai S, Upadhyay M, Nanda R. Dynamic smile analysis: changes with age. Am J Orthod Dentofacial Orthop. 2009 Sept;136(3):310.e1-10; discussion 310-1.
10. Thomas M, Reddy R, Reddy BJ. Perception differences of altered dental esthetics by dental professionals and laypersons. Indian J Dent Res. 2011 Mar-Apr;22(2):242-7.
11. Singh VP, Uppoor AS, Nayak DG, Shah D. Black triangle dilemma and its management in esthetic dentistry. Dent Res J (Isfahan). 2013 May;10(3):296-301.
12. Tarnow DP, Magner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. J Periodontol. 1992 Dec;63(12):995-6.
13. Pithon MM, Santos AM, Couto FS, de Freitas LMA, Coqueiro RS. Comparative evaluation of esthetic perception of black spaces in patients with mandibular incisor extraction. Angle Orthod. 2012 Sept;82(5):806-11.
14. Richards MR, Fields Júnior HW, Beck FM, Firestone AR, Walther DB, Rosenstiel S, et al. Contribution of malocclusion and female facial attractiveness to smile esthetics evaluated by eye tracking. Am J Orthod Dentofacial Orthop. 2015 Apr;147(4):472-82.
15. Talic N, Alomar S, Almaidhan A. Perception of Saudi dentists and lay people to altered smile esthetics. Saudi Dent J. 2013 Jan;25(1):13-21.

16. An SM, Choi SY, Chung YW, Jang TH, Kang KH. Comparing esthetic smile perceptions among laypersons with and without orthodontic treatment experience and dentists. Korean J Orthod. 2014 Nov;44(6):294-303.

17. Meyer-Marcotty P, Alpers GW, Gerdes ABM, Stellzig-Eisenhauer A. How others perceive orthognathic patients: an eye-tracking study. World J Orthod. 2010 Summer;11(2):153-9.

18. Farnsworth B. Eye tracking: the complete pocket guide. Imotion. December 4th, 2018 [Accessed: 2020 Nov 10] Available from: https://imotions.com/blog/eye-tracking/.

19. Tien T, Pucher PH, Sodergren MH, Sriskandarajah K, Yang GZ, Darzi A. Eye tracking for skills assessment and training: a systematic review. J Surg Res. 2014 Sept;191(1):169-178.

20. Dindaroglu F, Dogan S, Amado S, Dogan E. Visual perception of faces with unilateral and bilateral cleft lip and palate: an eye-tracking study. Orthod Craniofac Res. 2017 Feb;20(1):44-54.

21. Wang X, Cai B, Cao Y, Zhou C, Yang L, Liu R, et al. Objective method for evaluating orthodontic treatment from the lay perspective: an eye-tracking study. Am J Orthod Dentofacial Orthop. 2016 Oct;150(4):601-10.

22. Henderson JM, Hollingworth A. High-level scene perception. Annu Rev Psychol. 1999;50:243-71.

23. Henson ST, Lindauer SJ, Gardner WG, Shroff B, Tufekci E, Best AM. Influence of dental esthetics on social perceptions of adolescents judged by peers. Am J Orthod Dentofacial Orthop. 2011 Sept;140(3):389-95.

24. Kokich VO, Kokich VG, Kiyak HA. Perceptions of dental professionals and laypersons to altered dental esthetics: asymmetric and symmetric situations. Am J Orthod Dentofacial Orthop. 2006 Aug;130(2):141-51.

25. Linz C, Gerdes ABM, Meyer-Marcotty P, Muller-Richter U, Bohm H, Ernestus RI, et al. Perception of children's faces with unilateral coronal synostosis: an eye-tracking investigation. Childs Nerv Syst. 2016 Jan;32(1):135-41.

26. Krishnan V, Daniel ST, Lazar D, Asok A. Characterization of posed smile by using visual analog scale, smile arc, buccal corridor measures, and modified smile index. Am J Orthod Dentofacial Orthop. 2008 Apr;133(4):515-23.

27. Tanaka OM, Furquim BD, Pascotto RC, Ribeiro GLU, Bósio JA, Maruo H. The dilemma of the open gingival embrasure between maxillary central incisors. J Contemp Dent Pract. 2008 Sept 1;9(6):92-8.

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Zygomatic-maxillary cortical bone thickness in hyper, normo and hypodivergent patients

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ABSTRACT

Objective: The aim of this study was to evaluate the thickness of the zygomatic-maxillary cortical bone using computed tomography in different skeletal patterns.

Methods: A total of 54 patients of both sexes, divided into three groups according to the vertical skeletal pattern, were evaluated for cortical bone thickness of the anterior slope of the zygomatic process of the maxilla, using cone beam computed tomography. Measurements were made at 2mm, 4mm, 6mm, 8mm and 10mm above from first molar mesial root apex. Vertical skeletal pattern was determined by Frankfurt mandibular angle (FMA).

Results: The hyperdivergent pattern had the lowest cortical thickness value, nevertheless, no patient in the hyperdivergent group presented cortical thickness exceeding 2mm, and no patient in the hypodivergent group presented cortical thickness less than 1mm. However, the correlation between cortical thickness and mandibular plane angle was weak and not significant.

Conclusion: Although higher prevalence of thick cortical was observed in the hypodivergent patients, and thin cortical groups in the hyperdivergent group, the vertical skeletal pattern could not be used as determinant of the zygomatic-maxillary cortical thickness.

Keywords: Orthodontics. Orthodontic anchorage procedures. Cone beam computed tomography.

RESUMO

Objetivo: O objetivo do presente estudo foi avaliar a espessura da cortical óssea zigomático-maxilar por meio de tomografia computadorizada em diferentes padrões esqueléticos.

Métodos: Um total de 54 pacientes de ambos os sexos, divididos em três grupos, de acordo com o padrão esquelético vertical, foi avaliado quanto à espessura da cortical óssea na vertente anterior do processo zigomático da maxila, por meio de tomografia computadorizada de feixe cônico. As medidas foram feitas a 2mm, 4mm, 6mm, 8mm e 10mm acima do ápice da raiz mesial do primeiro molar. O padrão esquelético vertical foi determinado pelo Ângulo do Plano Mandibular (FMA).

Resultados: O padrão hiperdivergente apresentou o menor valor de espessura de cortical. No entanto, nenhum paciente do grupo hiperdivergente apresentou espessura cortical superior a 2mm e nenhum paciente do grupo hipodivergente apresentou espessura cortical inferior a 1mm. No entanto, a correlação entre a espessura da cortical e o ângulo do plano mandibular foi fraca e não significativa.

Conclusão: Embora tenha havido uma maior prevalência de cortical espessa no grupo hipodivergente e cortical fina no grupo hiperdivergente, o padrão esquelético vertical não pode ser utilizado como determinante da espessura cortical zigomático-maxilar.

Palavras-chave: Ortodontia. Procedimentos de ancoragem ortodôntica. Tomografia computadorizada de feixe cônico.

INTRODUCTION

The use of miniplates and other temporary anchorage devices (TADs), have increased the possibilities of orthodontic movement, such as intrusion and distalization of anterior and posterior teeth.[1,2]

Some studies have demonstrated success in the treatment of patients considered borderline for the indication of orthognathic surgery, when treated with the aid of these devices. However, the stability of TADs depends on the quality and thickness of the cortical bone, which may be related to the skeletal pattern of the patient.[3,4]

Miniplate fixation is obtained by mechanical retention in the cortical bone, therefore, justifying the dependence on adequate bone thickness[5]. Studies have suggested that patients with a vertical growth pattern tend to present lower thickness values of the buccal and lingual bone plates at the level and above the apex of permanent teeth, when compared with patients with a horizontal growth pattern. However, there are few studies specifically evaluating the area of the zygomatic pillar.[4-7]

Cone beam computed tomography enables cortical bone thickness measurement in a real proportion, without presenting distortions and with a relatively lower dose of radiation, compared to traditional computed tomography. The imaging resource is fundamental for measuring the cortical thickness, especially in the zygomatic-maxillary region, which has been widely used for insertion of TAD devices.[8-10]

Thus, the aim of this study was to evaluate the zygomatic-maxillary cortical bone thickness in different vertical skeletal patterns, using cone beam computed tomography images.

MATERIAL AND METHODS

The study sample consisted of volumetric computed tomography files of 54 patients (29 female and 25 male) from a database of tomography images belonging to a private Dental Radiology center (Maringá/PR, Brazil) and private clinic of professionals in the field of Dentistry in this same city.

The study was submitted to the Permanent Research Ethics Committee on Research Involving Human Beings (COPEP–UEM, *Universidade Estadual de Maringá)*, in accordance with the guidelines and regulatory rules on researches involving human beings (resolution nº. 196/96 of the National Council of Health), (CAAE #09159212.0.0000.0104).

Complete eruption of the permanent teeth from the right second molar to the left second molar was an inclusion criteria. Women at the stage of menopause and patients with craniofacial anomalies were excluded from the study.

The sample calculation was made for a test power of 80% and level of significance of 5%, standard deviation of 0.45 and difference to be detected of 0.5mm.[11] As a result, the number of 14 patients in each group was obtained.

Tomographs were taken in i-CAT® equipment (Imaging Sciences International, Hatfield, PA, USA) in single rotation (360º), 120 kvp, 23.87mAs and exposure time of 40 seconds. The protocol used was of the complete skull, with a 16 *x* 13 cm field of vision and voxel size of 0.3mm. The patients were oriented in a standardized position of the head, so that the Frankfurt plane would be set parallel to the ground, and the median sagittal plane, perpendicular to the ground. The images generated were saved in DICOM format (Digital Imaging and Communications in Medicine). Dolphin software®, version 11.7 Premium (Chatsworth, CA, USA) was used to evaluate the measurements.

For measurement procedure, the image was centralized on the axial slice, and the Frankfurt plane was positioned parallel to ground in sagittal slice. Anteroposterior cut was defined over the middle of the mesial-buccal root of the first permanent molar in each side. The measurements were taken on the coronal slice, with magnification of up to 200%, to facilitate visualization of the desired site, in a dark room, on a high-resolution monitor, by a single professional.

A reference line perpendicular to Frankfurt plane, starting from the apex of the mesiobucal root of the maxillary first molars, was drawn. On this perpendicular line, references lines (parallel to Frankfurt plane) were drawn at 2mm, 4mm, 6mm, 8mm and 10mm from the apex of the molars. Cortical bone thickness was evaluated in the intersection of this line to the anterior slope of zygomatic-maxillary bone, on both right and left sides of the maxilla (Fig 1).[10,12,13,14]

Measurement of the skeletal growth pattern was made on the lateral images (from the tomography), using the cephalometric variable FMA (Frankfurt Mandibular Plane Angle). Therefore, subjects with an angle between 21º and 29º were classified as normodivergent; those with an angle smaller than 21º or larger than 29º, were classified as hypodivergent and hyperdivergent, respectively.[4,15]

The sample was then divided into three groups: Group 1) Normodivergent (n = 23) (mean: 44.57 years; S.D.: 13.64); FMA (mean: 24.85; S.D: 2.58). Group 2) hypodivergent (n = 12) (mean: 44.75 years; S.D.: 15.09); FMA (mean: 16.05; S.D: 3.08) and Group 3) hyperdivergent (n = 19) (mean: 40.37 years; S.D.: 14.46); FMA (mean: 34.22; S.D: 4.66).

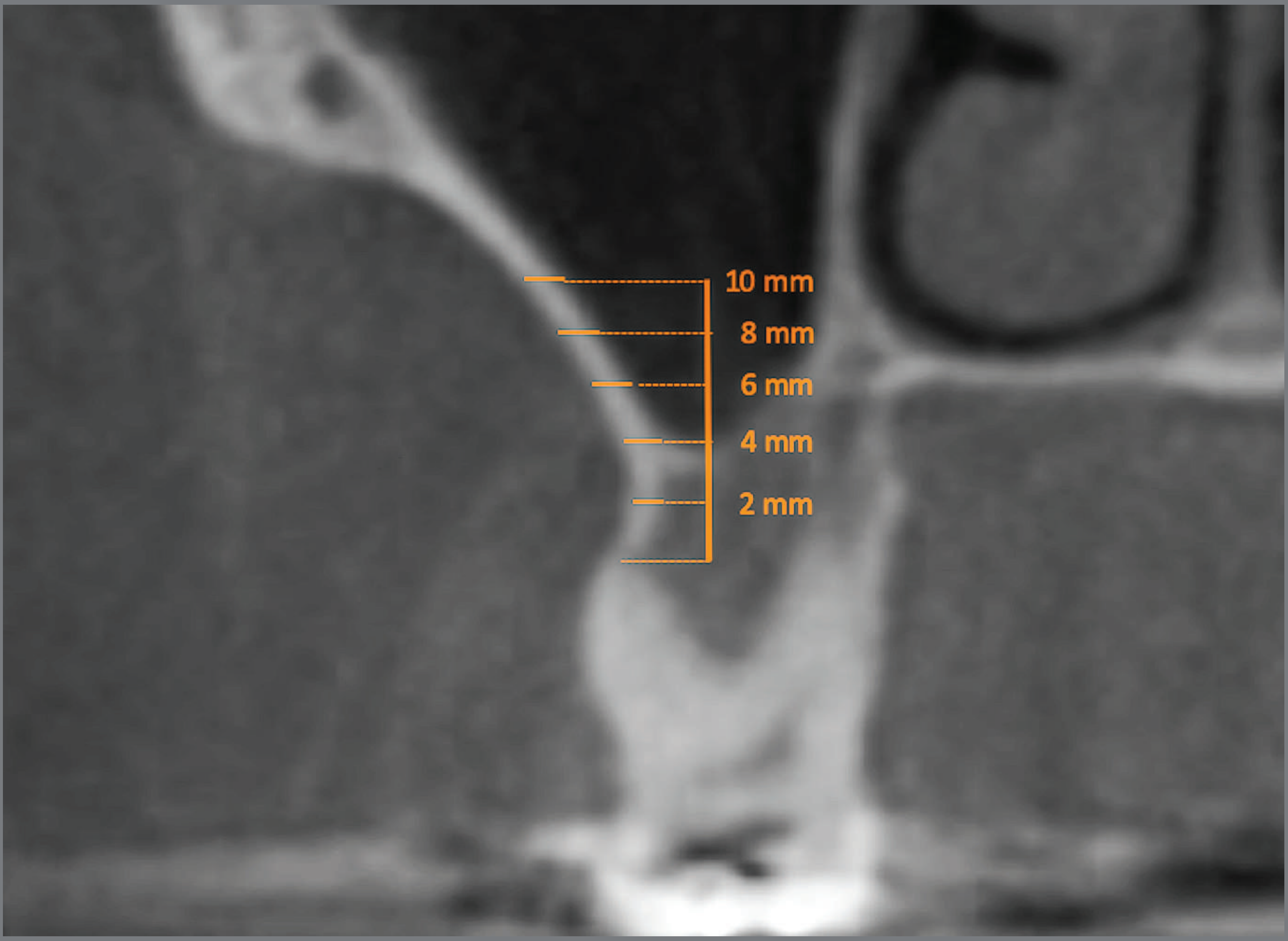

Figure 1: Reference lines used for the cortical bone thickness measurements.

The landmarks, lines and planes were established by a single operator. Twenty days after the first measurement, 13 images were traced again, to determine the reliability of the data. In a similar manner, 40 days after the initial stage, 13 images were drawn again, following the same references, and measurements of the buccal cortical bone thickness of the maxilla were taken.

STATISTICAL ANALYSIS

The Kolmogorov-Smirnov test was used to verify the sample distribution of the variables. In view of the normality of the data ($p < 0.05$), the *t*-test was used for comparison between the sides, and between the skeletal pattern and gender. ANOVA test was used for comparison between the groups.

The Pearson correlation test was applied to the cortical bone thickness *versus* skeletal growth pattern (FMA).

All statistical tests were performed with the Statistical Program (version 7.0; StatSoft Inc., Tulsa, OK, USA), adopting the level of significance for $p < 0.05$.

RESULTS

The results of systematic and random errors demonstrated reduced values (0,38 to 0.63), that were not significant.

The *t*-test for dependent samples showed no significant difference between the cortical bone thickness values between the right and left sides ($p < 0.05$) (Table 1). There were also no significant differences between the sexes within each group, or between the groups (Table 2). For these reasons, the groups were treated by using the means without distinction between sides and sex.

Table 1: Comparison among the mean cortical thickness values evaluated along the vestibular zygomatic-maxillary slope, by using the t-test for dependent samples, between the right and left sides.

	Right Side		Left Side		P
	Mean	S.D.	Mean	S.D.	
HYPERDIVERGENT					
2mm	1.44	0.44	1.40	0.46	0.80
4mm	1.30	0.39	1.28	0.32	0.86
6mm	1.19	0.32	1.23	0.35	0.71
8mm	1.19	0.26	1.29	0.34	0.28
10mm	1.22	0.24	1.27	0.40	0.64
Mean	1.40	0.29	1.39	0.30	0.91
NORMODIVERGENT					
2mm	1.85	0.78	1.69	0.49	0.35
4mm	1.67	0.75	1.46	0.37	0.19
6mm	1.50	0.58	1.43	0.38	0.58
8mm	1.37	0.49	1.53	0.64	0.29
10mm	1.36	0.49	1.53	0.61	0.24
Mean	1.67	0.56	1.63	0.38	0.74
HYPODIVERGENT					
2mm	1.65	0.59	1.47	0.36	0.37
4mm	1.45	0.53	1.31	0.3	0.44
6mm	1.43	0.57	1.24	0.32	0.30
8mm	1.37	0.45	1.29	0.49	0.65
10mm	1.48	0.58	1.30	0.46	0.40
Mean	1.57	0.51	1.42	0.38	0.39

Table 2: Comparison among the mean cortical thickness values evaluated along the vestibular zygomatic-maxillary slope, by using the *t*-test for dependent samples, between the skeletal pattern and sex.

	Male	Female	p
	$\overline{X}$ (S.D.)	$\overline{X}$ (S.D.)	
HYPODIVERGENT	1.50 (0.42)	1.35 (0.32)	0.46
NORMODIVERGENT	1.70 (0.50)	1.69 (0.36)	0.26
HYPERDIVERGENT	1.47 (0.14)	1.40 (0.27)	0.81

There was statistically significant difference between the mean values of buccal cortical bone thickness between the hyperdivergent and normodivergent patients, in the areas closer to the root apex (at 2mm, 4mm and 6mm). However, at 8mm and 10mm, there was no difference between groups (Table 3). Furthermore, Pearson correlation test between the buccal cortical bone thicknesses and the skeletal growth pattern (FMA) presented low values, that were not significant (Table 4).

Table 3: Comparison among the mean cortical thickness values evaluated along the vestibular zygomatic-maxillary slope, between the groups, by using one-way ANOVA.

	HYPERDIVERGENT (n=19)	NORMODIVERGENT (n=23)	HYPODIVERGENT (n=12)	*p*
2mm	1.42 (0.44)[A]	1.77 (0.65)[B]	1.56 (0.49)[AB]	0.01*
4mm	1.29 (0.35)[A]	1.57 (0.59)[B]	1.38 (0.44)[AB]	0.02*
6mm	1.21 (0.33)[A]	1.46 (0.49)[B]	1.34 (0.46)[AB]	0.02*
8mm	1.24 (0.30)[A]	1.45 (0.57)[A]	1.33 (0.46)[A]	0.09
10mm	1.24 (0.33)[A]	1.44 (0.56)[A]	1.39 (0.52)[A]	0.13
Média	1.39 (0.29)[A]	1.65 (0.47)[B]	1.50 (0.45)[AB]	0.01*

Table 4: Correlation between FMA angle and the cortical bone thickness.

Correlation	r	*p*
FMA x 2mm	-0.16	0.07
FMA x 4mm	-0.12	0.17
FMA x 6mm	-0.14	0.11
FMA x 8mm	-0.08	0.32
FMA x 10mm	-0.11	0.22
FMA x Mean	-0.15	0.09

DISCUSSION

Temporary anchorage devices have allowed tooth movements in patients considered borderline cases for orthognathic surgery. However, skeletal anchorage may not be stable, and this fact could be related to the cortical bone thickness, which differs among patients.[3,4] In this context, more studies about zigomatic cortical thickness are being encouraged, and the present study aimed at clarifying the anatomic variability of these areas.[4,6,16]

Recently, the importance of cortical thickness and bone density for the insertion of temporary anchorage in the infrazygomatic crest region and the mandibular ramus was reported, relating to possible failure of these devices.[13,16]

The hyperdivergent pattern may present thin cortical thickness values, as previously reported.[6] In fact, the buccal and lingual cortical bone in hypodivergent patients (ranging from 1.0mm to 2.6m) was thicker in comparison with that of hyperdivergent patients (ranging from 0.08 to 0.64mm) in the present study, however with no statistical significance.[4,15]

A tendency for thicker than 2.5mm cortical bone was observed in dry skulls mandibles from Japanese and Indian subjects.[6] In the present study, this trend was observed; however, closer to the maxillary sinus (at 8 mm and 10 mm), the mean difference among the facial patterns was not significant (Table 3).

Horner et al.[4] reported that hyperdivergent patients presented minimum cortical bone thickness values between 0.6 and 0.7mm, which were similar to those in the present study for subjects with dolicofacial pattern. These dimensions may represent a problem for the stability of screws in this area, considering that at least 1 mm thickness of cortical bone would be adequate.[15] For this reason, miniplate screws of increased diameter (between 2.3 and 2.5 mm) are used to overcome this limitation. Even so, in average a smaller area of cortical contact may be expected in hyperdivergent patients than in patients with other growth patterns. Hypodivergent and normodivergent patients in the present study presented minimum values of 1 and 0.9 mm respectively, limiting them to a lesser extent with regard to this requisite. Moreover, in subjects with a normodivergent and hypodivergent pattern, measurements of up to 3.4 mm thickness were found, and although the mean values of the groups did not differ significantly, there was a higher proportion of cases with thicker cortical among the hypodivergent patients.

No patient in the hyperdivergent group presented a thickness greater than 2 mm; and in the same way, no patient in the hypodivergent group presented a cortical thickness of less than 1 mm (Fig 2). It is worth emphasizing that these differences in behavior of the cortical bone were more evident up to distance of 6 mm above the root apex of the permanent maxillary first molars (Table 3). It is expected that higher insertion of the TAD relates to lower thickness of cortical bone for all the skeletal patterns.[16-18]

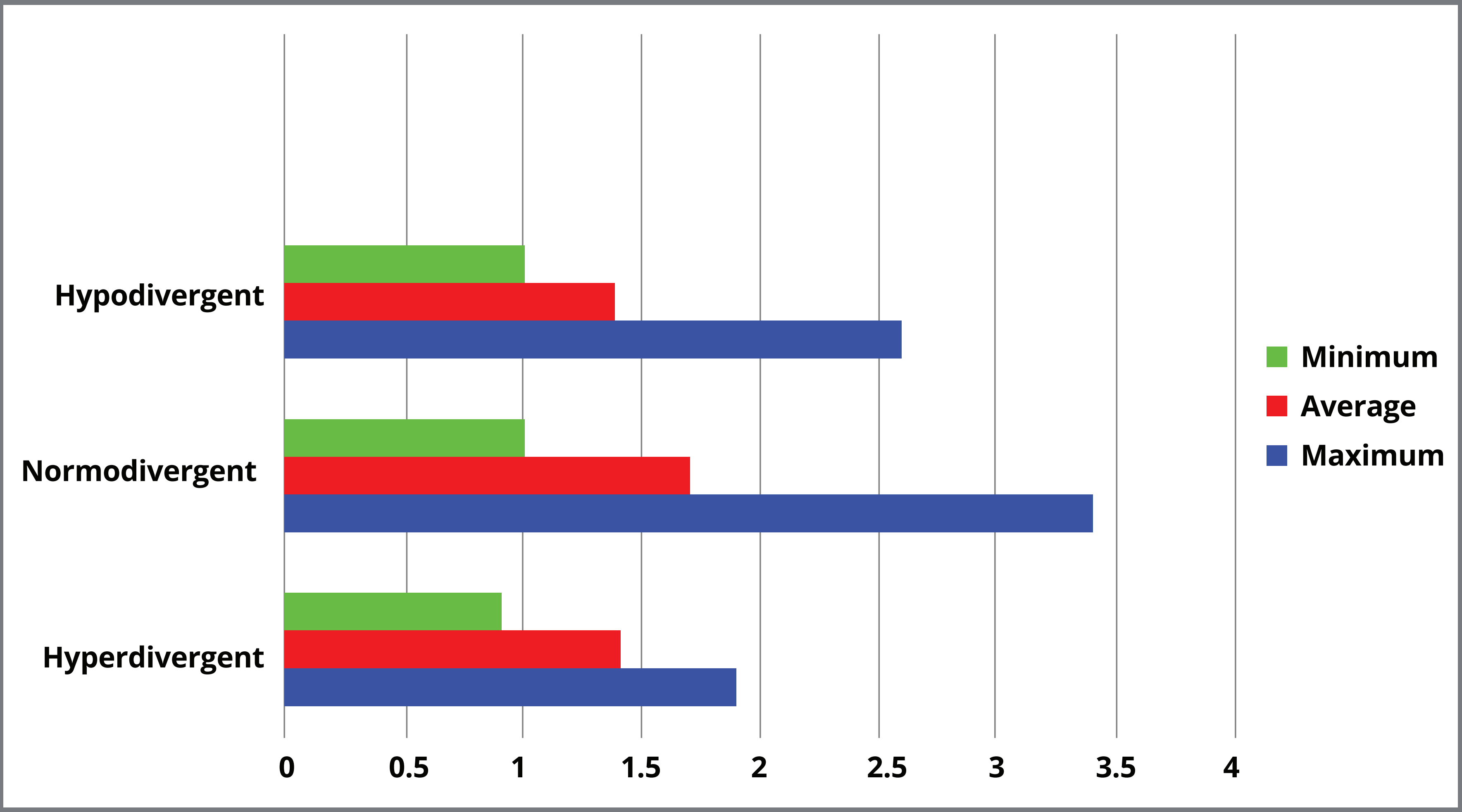

Figure 2: Comparative graph of measuring the cortical bone thickness along the vestibular zygomatic-maxillary slope among the hypodivergent, normodivergent and hyperdivergent cephalic patterns.

The results demonstrate that there was no significant correlation between zygomatic cortical bone thickness and skeletal pattern (FMA). Therefore, an individualized evaluation would be necessary, since one hyperdivergent patient may have a thick or a thin cortical bone, as well as a hypodivergent patient may have either thick or thin cortical thickness for TAD insertion.

CONCLUSION

Although there was higher prevalence of thick cortical in hypodivergent patients, and thin cortical in hyperdivergent group, skeletal pattern (FMA) could not be used as predictor for zygomatic-maxillary cortical bone thickness.

AUTHORS' CONTRIBUTION

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ALR, LIF.

Data acquisition, analysis or interpretation:

JVC, ALR, LIF.

Writing the article:

JVC, ALR.

Critical revision of the article:

JVC, ALR, LIF.

Final approval of the article:

JVC, ALR, LIF.

Overall responsibility:

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REFERENCES

1. Cornelis MA, Scheffler NR, De Clerck HJ, Tulloch JF, Behets CN. Systematic review of the experimental use of temporary skeletal anchorage devices in orthodontics. Am J Orthod Dentofacial Orthop. 2007 Apr;131(Suppl. 4):S52-8.
2. De Clerck EEB, Swennen GRJ. Success rate of miniplate anchorage for bone anchored maxillary protraction. Angle Orthod. 2011 Nov;81(6):1010-13.
3. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T. Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. Am J Orthod Dentofacial Orthop. 2006 Jun;129(6): 721.e7-12.
4. Horner KA, Behrents RG, Kim KB, Buschang PH. Cortical bone and ridge thickness of hyperdivergent and hypodivergent adults. Am J Orthod Dentofacial Orthop. 2012 Aug;142(2):170-8.
5. Santos AR, Castellucci M, Crusoé-Rebello IM, Sobral MC. Assessing bone thickness in the infrazygomatic crest area aiming the orthodontic miniplates positioning: a tomographic study. Dental Press J Orthod. 2017 July-Aug;22(4):70-6.
6. Masumoto T, Hayashi I, Kawamura A, Tanaka K, Kasai K. Relationship among facial type, buccolingual molar inclination, and cortical bone thickness of the mandible. Eur J Orthod. 2001 Feb;23(1):15-23.

7. Garib DG, Yatabe MS, Ozawa TO, Silva Filho OG. Alveolar bone morphology under the perspective of the computed tomography: defining the biological limits of tooth movement. Dental Press J Orthod. 2010 Sept-Oct;15(5):192-205.

8. Fayed MM, Pazera P, Katsaros C. Optimal sites for orthodontic mini-implant placement assessed by cone beam computed tomography. Angle Orthod. 2010 Sep; 80(5):939-51.

9. Liou EJ, Chen PH, Wang YC, Lin JC. A computed tomographic image study on the thickness of the infrazygomatic crest of the maxilla and its clinical implications for miniscrew insertion. Am J Orthod Dentofacial Orthop. 2007 Mar;131(3):352-6.

10. Kim G-T, Kim S-H, Choi Y-S, Park Y-J, Chung K-R, Suk K-E, et al. Cone-beam computed tomography evaluation of orthodontic miniplate anchoring screws in the posterior maxilla. Am J Orthod Dentofacial Orthop. 2009 Nov;136(5): 628.e1-10.

11. Menezes, CC. Influência do padrão de crescimento sobre a espessura da cortical óssea alveolar e sua correlação com a estabilidade dos mini-implantes [Dissertação de Mestrado]. Bauru, SP: Faculdade de Odontologia de Bauru; Universidade de São Paulo;2011.

12. Chaimanee P, Suzuki B, Suzuki EY. “Safe zones” for miniscrew implant placement in different dentoskeletal patterns. Angle Orthod. 2011 May;81(3):397-403.

13. Chang C, Liu SS, Roberts WE. Primary failure rate for 1680 extra-alveolar mandibular buccal shelf miniscrews placed in movable mucosa or attached gingiva. Angle Orthod. 2015 Nov;85(6):905-10.

14. Martinelli FL, Luiz RR, Faria M, Nojima LI. Anatomic variability in alveolar sites for skeletal anchorage. Am J Orthod Dentofacial Orthop. 2010 Sep;138(3):252.e1-9.

15. Moon CH, Park HK, Nam JS, Im JS, Baek SH. Relationship between vertical skeletal pattern and success rate of orthodontic mini-implants. Am J Orthod Dentofacial Orthop. 2010 Jul;138(1):51-7.

16. Chang CH, Roberts W. A retrospective study of the extra-alveolar screw placement on buccal shelves. Int J Ortho Implantol. 2013;32:80-9.

17. Motoyoshi M, Yoshida T, Ono A, Shimizu N. Effect of cortical bone thickness and implant placement torque on stability of orthodontic mini-implants. Int J Oral Maxillofac Implants. 2007 Sep-Oct;22(5):779-84.

18. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop. 2003 Oct;124(4):373-8.

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Miniscrew-assisted rapid palatal expansion (MARPE): how to achieve greater stability. *In vitro* study

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ABSTRACT

Objective: Assess the influence of mono- and bicortical anchorage and diameter of mini-implants (MIs) on the primary stability of these devices.

Methods: 60 self-drilling MIs were distributed in six groups according to diameter (1.5mm, 1.8mm or 2.0mm) and type of anchorage (monocortical and bicortical) in bovine rib. The primary stability was evaluated by insertion torque, micromobility and pull-out strength tests. ANOVA and/or Tukey analysis were used to conduct intergroup comparisons ($p < 0.05$). Non-parametric statistics (Kruskal-Wallis and Mann-Whitney) were performed when normality was not found ($p < 0.05$).

Results: MIs with larger diameters and bicortical anchorage showed greater primary stability regarding insertion torque ($p < 0.05$) and micromobility ($p < 0.05$). Only MI diameter had an effect on the pull-out strength test. Larger diameter MIs presented better retention in pull-out strength tests ($p < 0.001$), regardless of mono- or bicortical anchorage.

Conclusions: MI primary stability is dependent on its diameter and type of anchorage. Bicortical anchorage showed greater stability when compared with monocortical anchorage, independently of other variables.

Keywords: Dental materials. Orthodontic anchorage procedures. Palatal expansion technique.

RESUMO

Objetivo: Avaliar a influência da ancoragem mono e bicortical e do diâmetro dos mini-implantes (MIs) na estabilidade primária desses dispositivos.

Métodos: 60 MIs autoperfurantes foram distribuídos em seis grupos, de acordo com o diâmetro (1,5 mm, 1,8 mm ou 2,0 mm) e tipo de ancoragem (monocortical e bicortical), e inseridos em costela bovina. A estabilidade primária foi avaliada pelos testes de torque de inserção, micromobilidade e resistência à tração. ANOVA e/ou análise de Tukey foram usadas para realizar comparações intergrupos ($p < 0,05$). Estatística não paramétrica (Kruskal-Wallis e Mann-Whitney) foi realizada quando a normalidade não foi encontrada ($p < 0,05$).

Resultados: MIs com diâmetros maiores e ancorados bicorticalmente apresentaram maior estabilidade primária em relação ao torque de inserção ($p < 0,05$) e micromobilidade ($p < 0,05$). Apenas o diâmetro do MI influenciou os resultados do teste de resistência à tração. MIs de maior diâmetro apresentaram melhor retenção nos testes de resistência à tração ($p < 0,001$), independentemente da ancoragem mono ou bicortical.

Conclusões: a estabilidade primária do MI é dependente de seu diâmetro e tipo de ancoragem. A ancoragem bicortical apresentou maior estabilidade quando comparada à ancoragem monocortical, independentemente das demais variáveis.

Palavras-chave: Materiais dentários. Procedimentos de ancoragem ortodôntica. Técnica de expansão palatal.

INTRODUCTION

Orthodontic mini-implants (MIs) have greatly impacted orthodontic biomechanics and anchorage, since their advent. Movements that were very limited before, such as molar intrusion, became possible, and other routinely performed movements, such as molar distalization, were optimized.[1]

It is known that 20% of mixed dentition patients have maxillary constriction,[2] and the most popular treatment is rapid maxillary expansion (RPE). When RPE with a tooth-borne appliance is used to treat adolescents and young adults, it produces 35% skeletal orthopedic expansion and 65% dentoalveolar tipping.[3] RPE skeletal effects diminish with patient aging, because of the progressive calcification and interdigitation of circummaxillary sutures, and the decreased elasticity of bone in adults.[4]

In adult patients, where there is no potential for mid-palatal suture opening using conventional techniques, the treatment option is surgically-assisted rapid palatal expansion (SARPE).[5] However, this is a more invasive technique with considerable side effects, such as injury to the periodontium, root resorption,[6] sinus infection,[7] and injury to the branches of the maxillary nerve.[8] In addition, relapse of the transverse maxillary dimension has been demonstrated in the short term.[8] In 2010, MIs were associated with rapid palatal expanders for the first time[9] and are still yielding promising results. This expansion technique, known as miniscrew-assisted rapid palatal expansion (MARPE), can make the expansion more efficient in adolescents and young adults, and more feasible in elderly adults.[10] When well indicated, this technique can become a potential alternative to SARPE.[9,11]

From a clinical point of view, bicortical anchorage should be used in cases where heavy anchorage is desired.[12] The use of MIs allows tooth-bone-borne palatal expanders to apply forces directly into the basal bone, thus bringing horizontal expansion forces close to the midpalatal suture and right into the maxillary center of resistance.[9] Thus, MI stability is essential to resist the magnitude of the applied mechanical forces required to open the heavily interdigitated circum-maxillary sutures.

However, with the promising use of MARPE on the rise, many doubts regarding technical specifications have arisen, such as: What is the most appropriate length and diameter of the MI?; How deep should the MI be inserted into the bone?; What is the best mechanical position for the jackscrew in the sagittal and vertical planes? These questions should be addressed scientifically by laboratorial and clinical trials.

Few laboratorial studies have demonstrated that the MI diameter has a direct influence on its primary stability, and others have suggested that bicortical anchorage might impact it as well.[13,14] However, to our knowledge, no study has assessed the influence of these two factors simultaneously on MI primary stability. Our hypothesis is based on the possibility that larger diameters MI could positively influence the stability of these devices, as well as the bicortical anchorage.

The aim of this study was to compare the effects of monocortical and bicortical anchorage of MIs with different diameters on their primary stability, through mechanical *in vitro* tests.

MATERIAL AND METHODS

The project was approved by the Animal Ethics Committee of the Center for Health Sciences of the Federal University of Rio de Janeiro before the study began, under number 01200.001588/2013-87.

Sixty commercially available cylindrical self-drilling MIs (6 mm length) made of Ti-6Al-4V alloy (Conexão Implantes, São Paulo, SP, Brazil), were allocated into six groups (n=10), according to their diameter and insertion depth (monocortical or bicortical) (Fig 1). The number of samples was calculated using the sample size data of a previous pilot study (SD = 0.06, α = 5%, power of study = 80%). Sixty sections (8 mm ø) were removed from a bovine rib (*Bos taurus indicus*, Nelore lineage) with a trephine bur (8 mm ø x 20 mm long, Sin Implantes, São Paulo, SP, Brazil) and stored by freezing (-20°C) (Fig 1). All the specimens had approximately 1 mm of cortical bone (on the top and bottom) and two types of trabecular bone length (4 mm and 5 mm) to achieve the monocortical or bicortical insertion procedure (Fig 2).

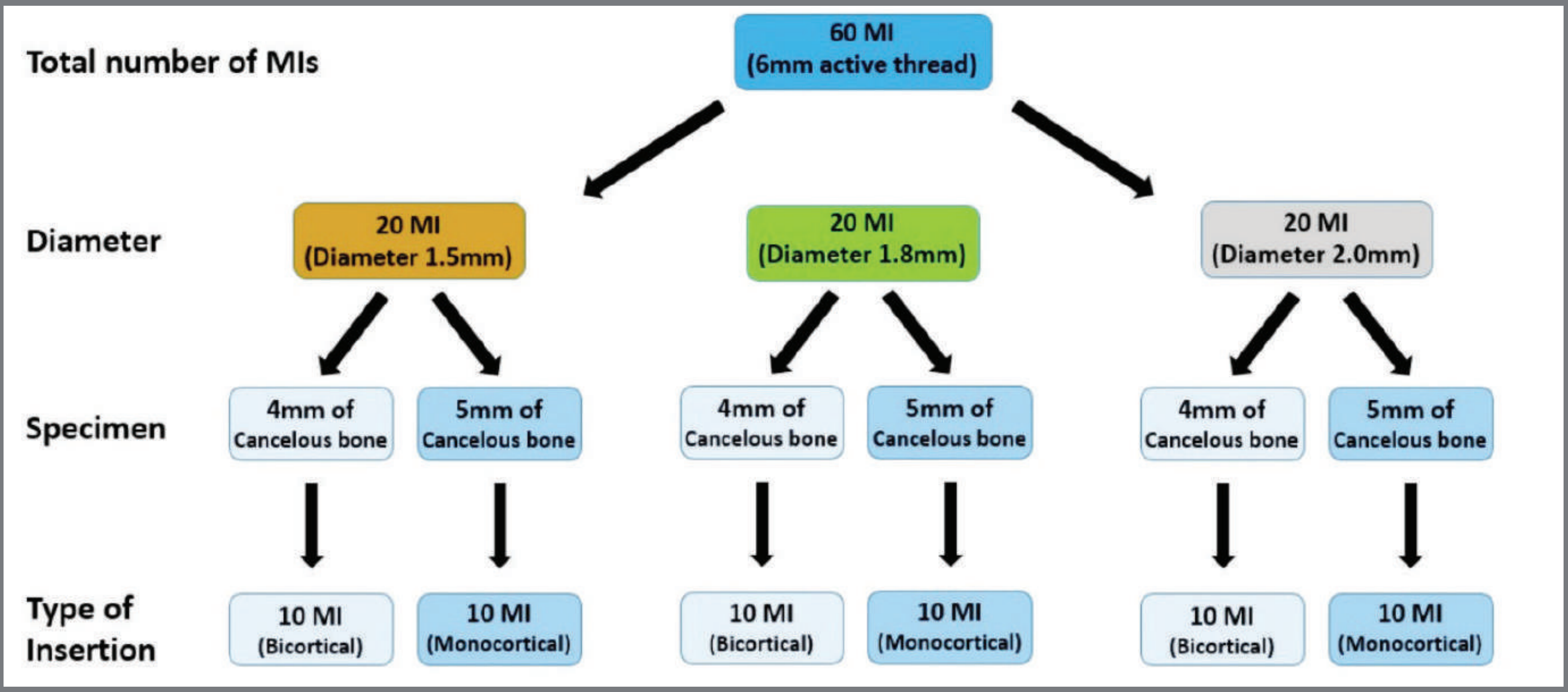

Figure 1: Flowchart showing distribution of specimens into the groups/subgroups according to their diameter and type of insertion.

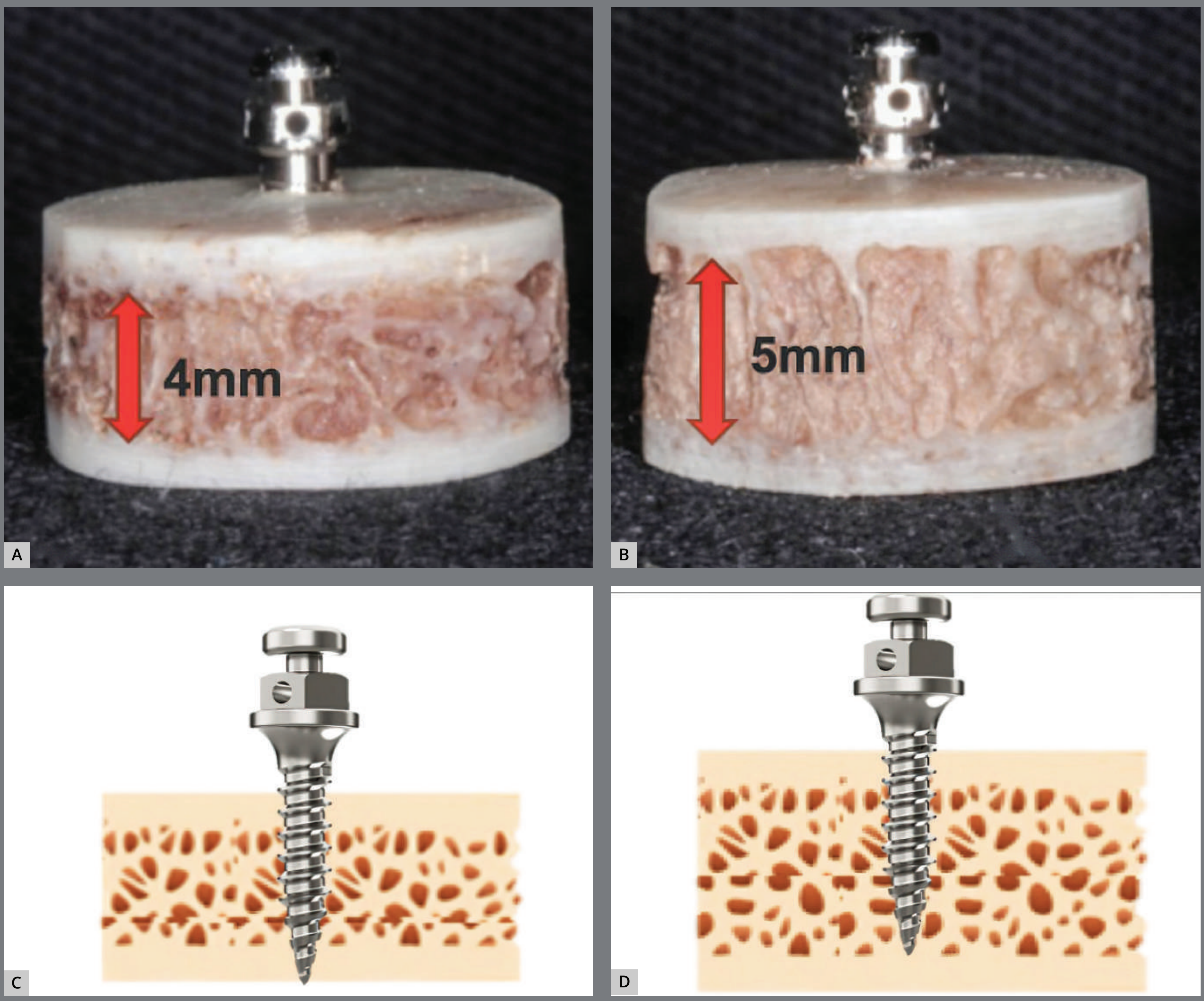

Figure 2: Specimens simulating palate according to trabecular bone thickness and mini-implant insertion depth diagram. **A)** 4 mm **B)** 5 mm **C)** Bicortical anchorage **D)** Monocortical anchorage.

ASSESSMENT OF MINI-IMPLANT PRIMARY STABILITY

Insertion torque (IT)

The MI sites were predrilled with a lance (Orthodontic Kit, INP system, São Paulo, Brazil) to a depth of 1 mm, following the protocol of a previous study.[15] The insertion was conducted by a single operator by using a manual key connected to a digital torque meter (Lutron TQ-8800, Taipei, Taiwan). Each MI was inserted until all the threads were fully contained in the block. A mechanical device was used to align the torque meter, the MI and the bone blocks, maintaining the system in a perpendicular relationship. The peak insertion torque values were recorded in Newton centimeters (Ncm).

Mini-implant mobility

MI mobility was evaluated with the Periotest® instrument (Medizintechnik Gulden, Modautal, Germany). A special acrylic device was used to fix both the sample and Periotest® handpiece, and to standardize the distance between the sleeve and the MI.[16] The handpiece was calibrated before each screw was measured. Two recordings were collected for each MI, and the average value was designated as the Periotest value (PTV), ranging on a scale from -8 to +50, where the smaller the PTV value, the smaller the micromobility and the higher the primary stability.

Pull-out strength (PS)

This test was conducted in a universal testing machine (EMIC DL 2000, São José dos Pinhais, PR, Brazil) connected to a 500 Kgf load cell. Two stainless steel devices were developed especially for the purpose of maintaining exact axial coincidence of the system. A crosshead speed of 5 mm per minute was selected, based on the American Standard Specification and Test Methods (F543-07) guidelines for metallic medical bone screws, and the maximum PS was recorded in Newtons (N).

STATISTICAL ANALYSIS

Statistical analysis was performed with the SPSS software (version 22, SPSS Inc, Chicago, IL, USA). The two-way ANOVA test was used to evaluate the interaction of the MI diameter (1.5 mm, 1.8 mm and 2.0 mm) and the insertion depth (monocortical or bicortical). Normality was verified by the Kolmogorov-Smirnov test, and homogeneity of variances, by the Levene test. When the main effect was observed for the diameter factor (no interaction), the *post-hoc* Tukey test was used to determine intergroup comparisons. When an interaction was verified between diameter and bone insertion, the effect of the interaction was contrasted to determine the differences between the groups. When normality and/or homogeneity of variances was violated, a nonparametric statistic was applied: Kruskal-Wallis test with the comparisons between pairs analyzed by the Mann-Whitney test. The level of significance was set at 5%.

RESULTS

The insertion torque results are displayed in Figure 3. Mechanical performance was clearly influenced by MI diameter and type of anchorage, given that higher insertion torque values were found in devices with greater diameter and bicortical insertion ($p < 0.001$). In addition, the insertion torque values for all the diameters evaluated were higher in the MIs with bicortical insertion (Bicortical: 1.5ø: 24.61 ± 0.47; 1.8ø: 28.13 ± 0.18; 2.0ø: 37.00 ± 0.19 / Monocortical: 1.5ø: 16.66 ± 0.45; 1.8ø: 18.95 ± 0.33; 2.0ø: 29.67 ± 0.34).

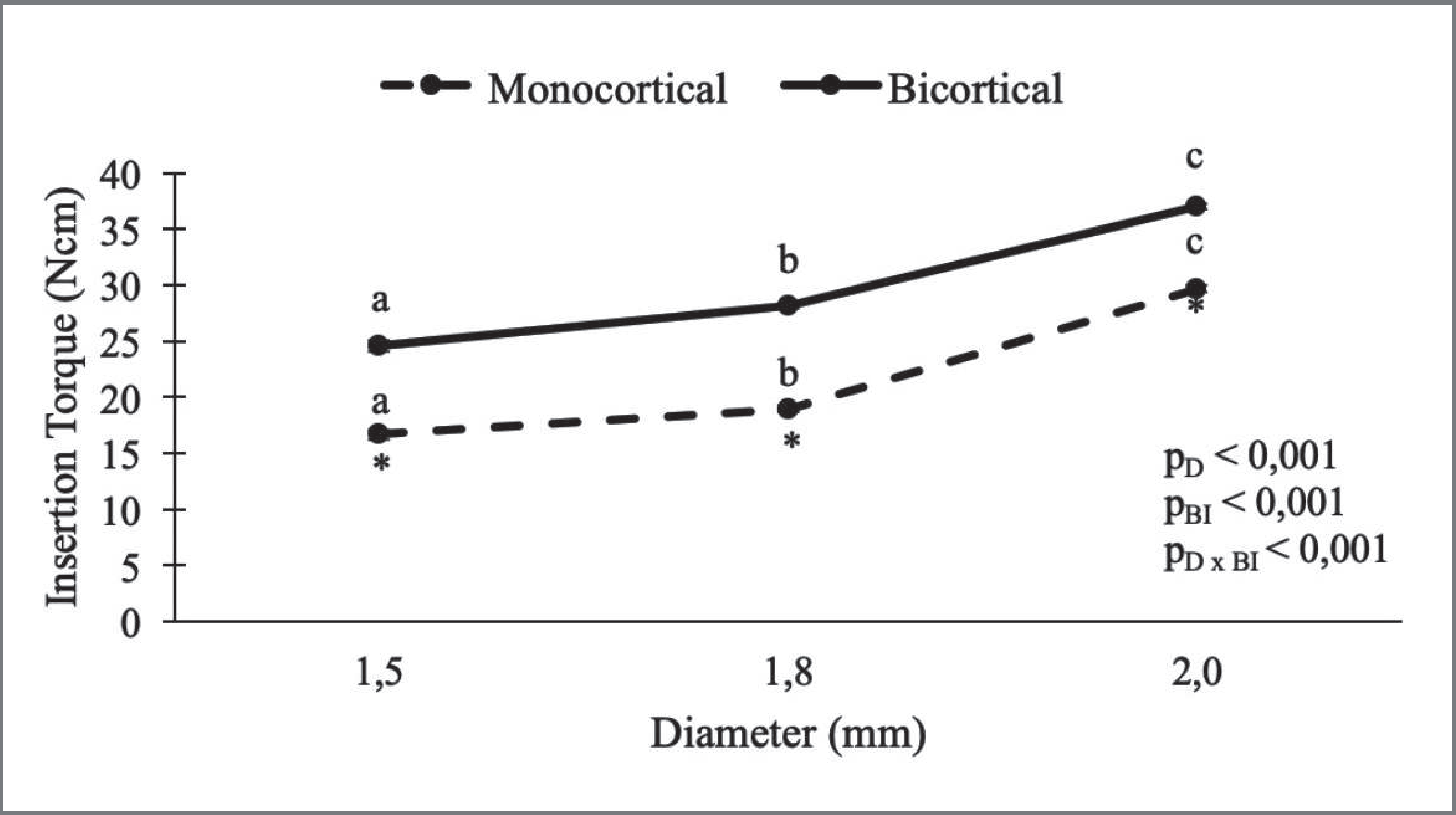

Figure 3: Graph showing insertion torque (IT) analysis (D=Diameter; BI=Bone Insertion**)**. Higher IT values were found in mini-implants with greater diameter and bicortical insertion. * ANOVA two-way: a, b, c distinct letters indicate statistical difference (p ≤ 0.05).

Mobility (Fig 4) was influenced by insertion type and MI diameter. MI mobility for both types of insertion decreased as diameter increased. The lowest mobility was found in the 2.0-mm diameter MI with bicortical insertion (Bicortical: 1.5ø: 14.00 ± 0.06; 1.8ø: 9.00 ± 0.80; 2.0ø: 1.00 ± 1.00 / Monocortical: 1.5ø: 17.75 ± 1.10; 1.8ø: 14.25 ± 0.60; 2.0ø: 4.50 ± 0.60).

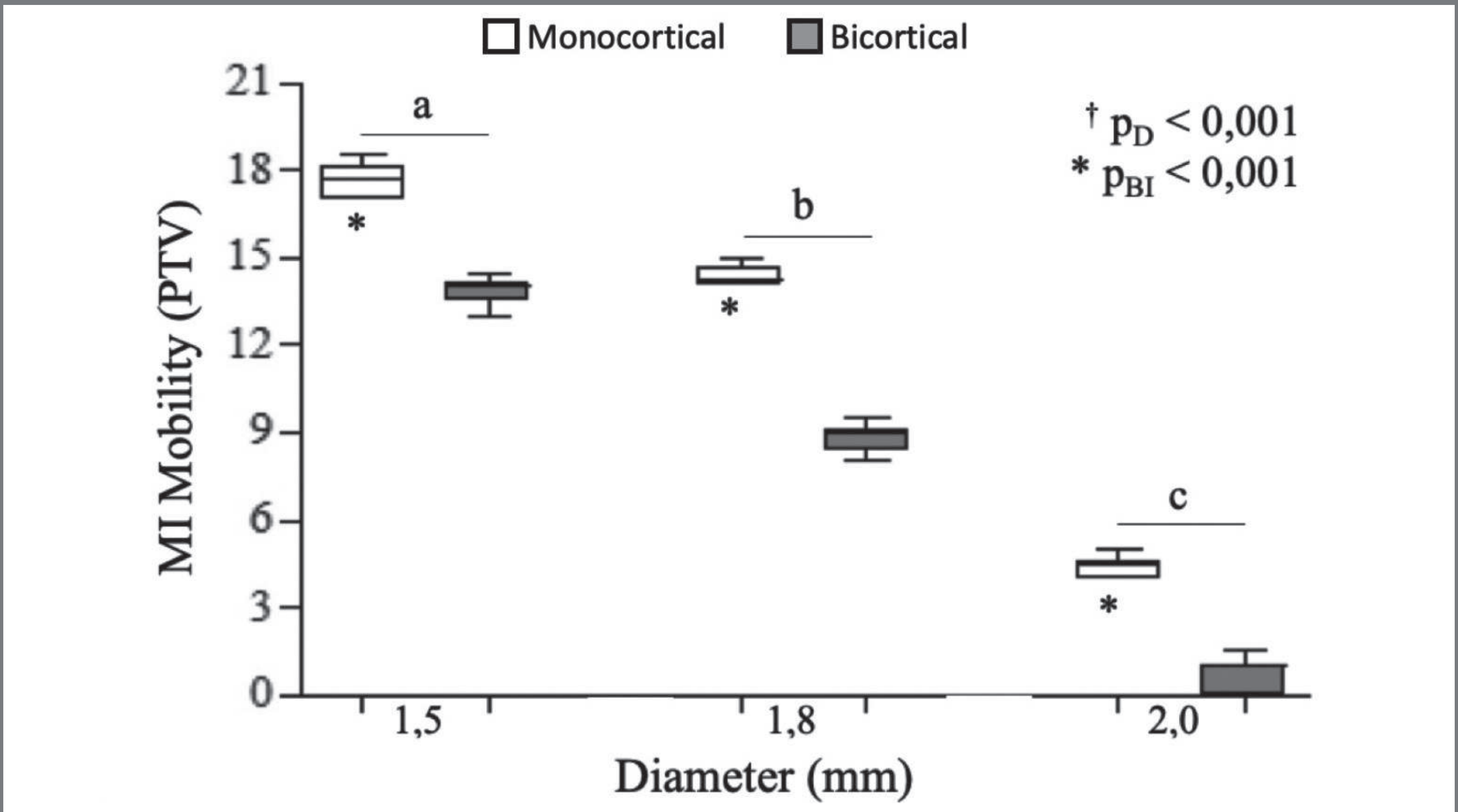

Figure 4: Graph showing Periotest assessment (D= Diameter; BI=Bone Insertion). The results indicated influence of diameter and insertion type on mobility. Mini-implant mobility was statistically lower for mini-implants with larger diameters regardless of anchorage insertion type. * Kruskal-Wallis test: a, b, c distinct letters indicate statistical difference between the diameters (Mann-Whitney test); † Mann-Whitney test.

Only MI diameter influenced pull-out strength values; MIs with larger diameter were more resistant to traction (Fig 5), regardless of mono- or bicortical insertion. (Bicortical: 1.5ø: 125.58 ± 4.84; 1.8ø: 181.87 ± 3.98; 2.0ø: 271.41 ± 3.70 / Monocortical: 1.5ø: 124.23 ± 4.10; 1.8ø: 182.78 ± 2.87; 2.0ø: 268.40 ± 5.05).

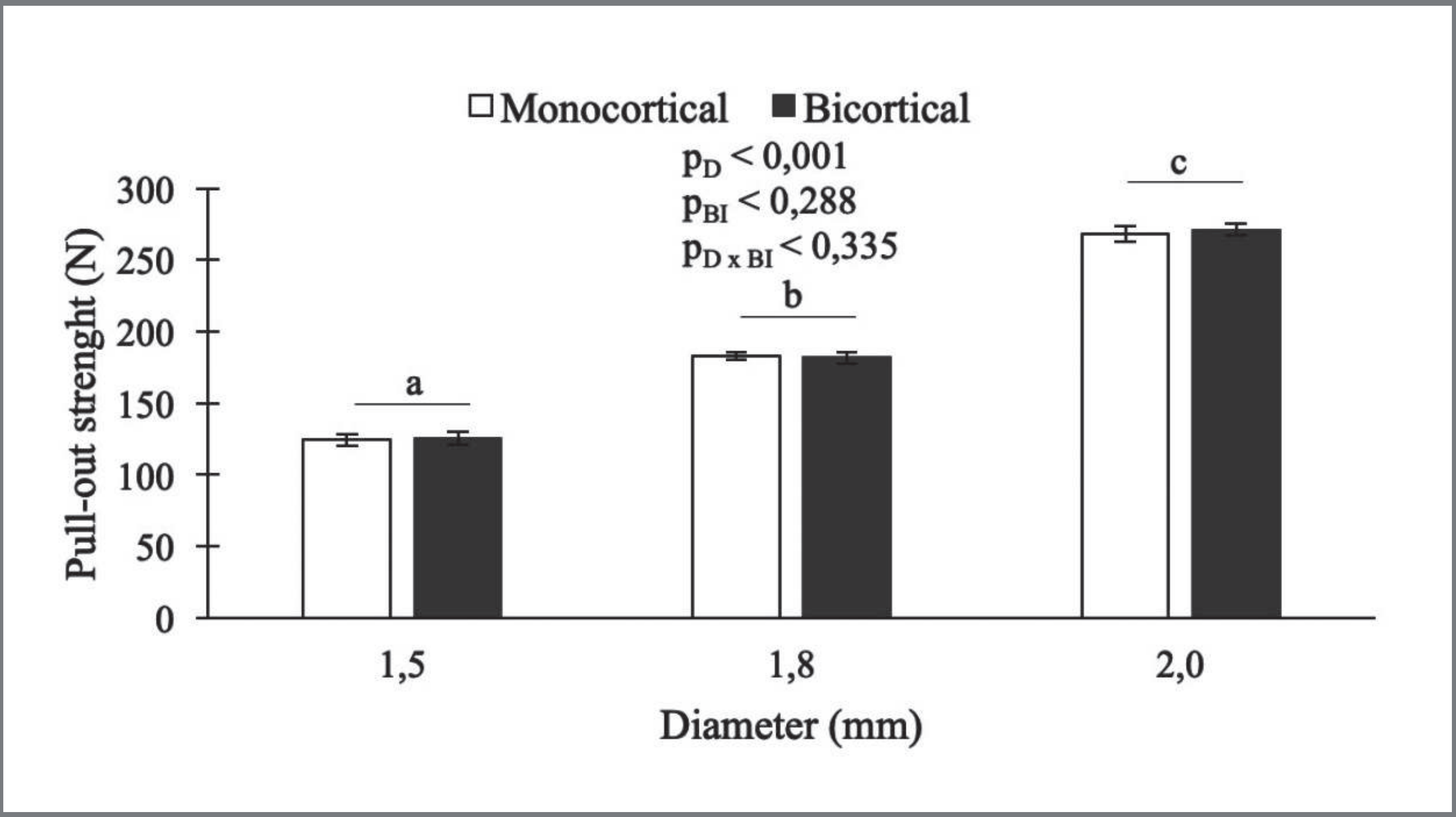

Figure 5: Graph showing pull-out strength results. (D= Diameter; BI=Bone Insertion). Only mini-implant diameter influenced pull-out strength values.

Table 1: Descriptive statistics for Insertion Torque and Pull-out Strength.

Primary Stability Tests	BI	Diameter (D)			Effect	*p-valor
		1.5 mm	1.8 mm	2.0 mm		
Insertion Torque (Ncm)					D	< 0.001
	MC	16.66 ± 0.45[a]	18.95 ± 0.33[b]	29.67 ± 0.34[c]	BI	< 0.001
	BC	24.61 ± 0.47[a†]	28.13 ± 0.18[b†]	37.00 ± 0.19[c†]	D x BI	< 0.001
Pull-out Strength (N)		a	b	c	D	< 0.001
	MC	124.23 ± 4.10	182.78 ± 2.87	268.40 ± 5.05	BI	0.288
	BC	125.58 ± 4.84	181.87 ± 3.98	271.41 ± 3.70	D x BI	0.335

D, Diameter; BI, Bone Insertion; D x BI, effect between diameter and bone insertion; MC, monocortical; BC, bicortical. Results are expressed as mean ± standard deviation. * ANOVA two-way: a, b, c distinct letters indicate statistical difference (p ≤ 0.05) between the diameters, according to the comparisons for interaction effect (insertion torque) and Tukey test (pull-out strength) ; † indicates statistical difference (p ≤ 0.05) between types of bone insertion.

Table 2: Descriptive statistics for mini-implant micromobility.

Bone Insertion	Diameter			*p-valor
	1.5 mm	1.8 mm	2.0 mm	
Monocortical	17.75 ± 1,10[a]	14.25 ± 0,60[b]	4.50 ± 0.60[c]	< 0.001
Bicortical	14.00 ± 0,06[a]	9.00 ± 0,80[b]	1.00 ± 1.00[c]	< 0.001
†p-valor	< 0.001	< 0.001	< 0.001	

The results are expressed as median ± interquartile amplitude. * Kruskal-Wallis test: a, b, c distinct letters indicate statistical difference between the diameters (Mann-Whitney test); † Mann-Whitney test.

DISCUSSION

With the introduction of the MARPE technique as a possible alternative to SARPE, several studies have been published to evaluate its efficacy in treating transverse maxillary deficiency.[10,17-20] Adequate MI stability is imperative for resisting the loads employed during activation of the expander, especially in adults, where greater interdigitation of the sutures requires higher mechanical loads.

In the present study, the MIs were selected with the same length of active threads to standardize both the insertion, with all the active threads of the MI inserted into the bone, and the same transmucosal portion leading out of the specimen, in order to reduce the moment of force variable.

We used bovine rib because it has been validated as a bone model in other biomechanical studies.[21,22] In addition, the thickness of the bovine rib in selected areas allows the simulation of monocortical and bicortical anchorage.

Since the MARPE technique is relatively recent, the primary stability and mechanical performance of the MI must be evaluated when it is correlated with the type of anchorage (mono- and bicortical). In this study, primary stability parameters such as insertion torque, Periotest® and pull-out values were used as stability predictors.[23,24]

Studies with finite element methods (FEM) were used to simulate the effectiveness of the midpalatal opening, the expansion resistance and the MI stability when using a tooth-bone-borne palatal expander.[12,25,26] The present study corroborates previous reports that used FEM[12,25] with better mechanical results (insertion torque and Periotest® values) for MIs inserted with bicortical versus monocortical anchorage. The study by Lee et al.[12] showed that bicortical anchorage was more effective to open the midpalatal suture and to prevent the distortion of the device, in comparison with monocortical anchorage. Therefore, a positive correlation seems to exist between MI stability and effectiveness of the expansion. Specifically, greater MI stability provides better device resistance against expansion forces. Furthermore, the positive correlation observed between bicortical anchorage and low Periotest® values ($p < 0.05$) indicates the potential of bicortical anchorage against lateral forces.

In contrast, a study by Poorsattar-Bejeh[26] using FEM showed that monocortical anchorage provided greater stability compared with bicortical anchorage, based on the pull-out test during FEM simulation. In our study, although the results showed better mechanical performance of MIs when inserted with bicortical anchorage, differences were not statistically significant.

A positive correlation was found in different studies between larger MI diameter and better mechanical performance.[27-29] Pimentel et al.[14] found (*in vitro*) that all MIs with a diameter of 1.8 mm, 2.0 mm and 2.2 mm, used with the MARPE technique, endured loads beyond those clinically necessary for breaking loose the midpalatal suture in maxillary expansion. We found that MIs with a diameter of 2.0 mm and 1.8 mm inserted with monocortical anchorage had better mechanical outcomes, compared with a 1.5 mm diameter inserted with bicortical anchorage. Therefore, MIs with larger diameters are recommended, since they deliver good mechanical stability, and since bicortical anchorage may not always be clinically achieved due to the sensitivity of the technique. Moreover, MIs of greater diameter should be used with tooth-bone-borne expanders in the anterior portion of the palate, where bicortical anchorage is not always possible.

It is known that the results achieved with primary stability influence secondary stability and permanence of the MI. When the MI is well stabilized to allow it to receive the necessary load, the chances of successful treatment are greater.[30]

Because of the inherent limitations of *in vitro* studies and mechanical tests, future studies using conventional clinical model analysis are needed to confirm our results. We also suggest that a mechanical *in vitro* analysis of the MI be conducted using the MARPE expander, bearing in mind that a microstructural assessment of the bone should also be made when this type of device is used.

CONCLUSIONS

The following conclusions can be drawn:

• Mini-implant primary stability is dependent on the diameter and the type of anchorage (mono- or bicortical) of the device.

• Mini-implants inserted with bicortical anchorage had better mechanical results, compared with monocortical anchorage

• Devices with a 2.0-mm diameter had better results, even when bicortical anchorage was not achieved.

AUTHORS' CONTRIBUTION

Flávio de Mendonça Copello (FMC):
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Carlos Nelson Elias (CNE):
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FMC, DPB, CNE, MMP, RSC, ACRC, EFS.
Data acquisition, analysis or interpretation:
FMC, DPB, CNE, MMP, RSC, ACRC, EFS.
Writing the article:
FMC, DPB, CNE, MMP, RSC, ACRC, EFS.
Critical revision of the article:
FMC, DPB, CNE, MMP, RSC, ACRC, EFS.
Final approval of the article:
FMC, DPB, CNE, MMP, RSC, ACRC, EFS.
Fundraising:
FMC, DPB, CNE, MMP, RSC, ACRC, EFS.
Overall responsibility:
FMC, DPB, CNE, MMP, RSC, ACRC, EFS.

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REFERENCES

1. Tekale PD, Vakil KK, Vakil JK, Gore KA. Distalization of maxillary arch and correction of Class II with mini-implants: a report of two cases. Contemp Clin Dent. 2015;6(2):226-32.
2. Brunelle JA, Bhat M, Lipton JA. Prevalence and distribution of selected occlusal characteristics in the US population, 1988-1991. J Dent Res. 1996;75(no. spec.):706-13.
3. Krebs A. Midpalatal suture expansion studies by the implant method over a seven-year period. Rep Congr Eur Orthod Soc. 1964;40:131-42.
4. Persson M, Thilander B. Palatal suture closure in man from 15 to 35 years of age. Am J Orthod. 1977;72(1):42-52.
5. Harzer W, Schneider M, Gedrange T, Tausche E. Direct bone placement of the hyrax fixation screw for surgically assisted rapid palatal expansion (SARPE). J Oral Maxillofac Surg. 2006;64(8):1313-7.
6. Mommaerts MY. Transpalatal distraction as a method of maxillary expansion. Br J Oral Maxillofac Surg. 1999;37(4):268-72.
7. Feller KU, Herzmann K, Schimming R, Eckelt U. [Glassman palatine expansion. Experiences with mono- and bimaxillary dysgnathia operations]. Mund - Kiefer - Gesichtschir. 1998;2(1):26-9.

8. Suri L, Taneja P. Surgically assisted rapid palatal expansion: a literature review. Am J Orthod Dentofacial Orthop. 2008;133(2):290-302.

9. Lee KJ, Park YC, Park JY, Hwang WS. Miniscrew-assisted nonsurgical palatal expansion before orthognathic surgery for a patient with severe mandibular prognathism. Am J Orthod Dentofacial Orthop. 2010;137(6):830-9.

10. Cantarella D, Dominguez-Mompell R, Mallya SM, Moschik C, Pan HC, Miller J, et al. Changes in the midpalatal and pterygopalatine sutures induced by micro-implant-supported skeletal expander, analyzed with a novel 3D method based on CBCT imaging. Prog Orthod. 2017;18(1):34-46.

11. Kim KB, Helmkamp ME. Miniscrew implant-supported rapid maxillary expansion. J Clin Orthod. 2012;46(10):608-12.

12. Lee RJ, Moon W, Hong C. Effects of monocortical and bicortical mini-implant anchorage on bone-borne palatal expansion using finite element analysis. Am J Orthod Dentofacial Orthop. 2017;151(5):887-97.

13. Holberg C, Winterhalder P, Rudzki-Janson I, Wichelhaus A. Finite element analysis of mono- and bicortical mini-implant stability. Eur J Orthod. 2014;36(5):550-6.

14. Pimentel AC, Manzi MR, Prado Barbosa AJ, Cotrim-Ferreira FA, Guedes Carvalho PE, Lima GF, et al. Mini-implant screws for bone-borne anchorage: a biomechanical in vitro study comparing three diameters. Int J Oral Maxillofac Implants. 2016;31(5):1072-6.

15. Cunha AC, Marquezan M, Lima I, Lopes RT, Nojima LI, Sant'Anna EF. Influence of bone architecture on the primary stability of different mini-implant designs. Am J Orthod Dentofacial Orthop. 2015;147(1):45-51.

16. Marquezan M, Souza MMG, Araújo MTS, Nojima LI, Nojima MCG. Is miniscrew primary stability influenced by bone density? Braz Oral Res. 2011;25(5):427-32.

17. Lim HM, Park YC, Lee KJ, Kim KH, Choi YJ. Stability of dental, alveolar, and skeletal changes after miniscrew-assisted rapid palatal expansion. Korean J Orthod. 2017;47(5):313-22.

18. Carlson C, Sung J, McComb RW, Machado AW, Moon W. Microimplant-assisted rapid palatal expansion appliance to orthopedically correct transverse maxillary deficiency in an adult. Am J Orthod Dentofacial Orthop. 2016;149(5):716-28.

19. Brunetto DP, Sant'Anna EF, Machado AW, Moon W. Non-surgical treatment of transverse deficiency in adults using Microimplant-assisted Rapid Palatal Expansion (MARPE). Dental Press J Orthod. 2017;22(1):110-25.

20. Cunha ACD, Lee H, Nojima LI, Nojima MDCG, Lee KJ. Miniscrew-assisted rapid palatal expansion for managing arch perimeter in an adult patient. Dental Press J Orthod. 2017;22(3):97-108.

21. García-Vives N, Andrés-García R, Rios-Santos V, Fernández-Palacín A, Bullón-Fernández P, Herrero-Climent M, et al. In vitro evaluation of the type of implant bed preparation with osteotomes in bone type IV and its influence on the stability of two implant systems. Med Oral Patol Oral Cir Bucal. 2009;14(9):e455-60.

22. Bataineh AB, Al-Dakes AM. The influence of length of implant on primary stability. J Clin Exp Dent. 2017;9(1):e1-e6.

23. Brinley CL, Behrents R, Kim KB, Condoor S, Kyung HM, Buschang PH. Pitch and longitudinal fluting effects on the primary stability of miniscrew implants. Angle Orthod. 2009;79(6):1156-61.

24. Pithon MM, Nojima MG, Nojima LI. Primary stability of orthodontic mini-implants inserted into maxilla and mandible of swine. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012;113(6):748-54.

25. Moriwaki H, Yamaguchi S, Nakano T, Yamanishi Y, Imazato S, Yatani H. Influence of implant length and diameter, bicortical anchorage, and sinus augmentation on bone stress distribution: three-dimensional finite element analysis. Int J Oral Maxillofac Implants. 2016;31(4):84-91.

26. Poorsattar-Bejeh Mir A. Monocortical versus bicortical hard palate anchorage with the same total available cortical thickness: a finite element study. J Investig Clin Dent. 2017;8(3):1-9

27. Schatzker J, Sanderson R, Murnaghan JP. The holding power of orthopedic screws in vivo. Clin Orthop Relat Res. 1975; (108):115-26.

28. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop. 2003;124(4):373-8.

29. Chang JZ, Chen YJ, Tung YY, Chiang YY, Lai EH, Chen WP, et al. Effects of thread depth, taper shape, and taper length on the mechanical properties of mini-implants. Am J Orthod Dentofacial Orthop. 2012;141(3):279-88.

30. Lim SA, Cha JY, Hwang CJ. Insertion torque of orthodontic miniscrews according to changes in shape, diameter and length. Angle Orthod. 2008;78(2):234-40.

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McNamara analysis cephalometric parameters in White-Brazilians, Japanese and Japanese-Brazilians with normal occlusion

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ABSTRACT

Introduction: McNamara's Jr. cephalometric analysis is a tool to diagnose dental and skeletal discrepancies and is widely used, guiding diagnosis for surgical procedures to be performed or for the use of functional devices. Few studies have shown that different ethnic groups have different cephalometric patterns. Thus, single characteristics should be respected to support the diagnosis and to help the treatment plan for different ethnic groups and their different patterns of miscegenation.

Objective: Obtain normal values for McNamara's cephalometric analysis for adolescent Japanese-Brazilian descents with normal occlusion, as well as to compare this sample with similar samples of White-Brazilian and Japanese.

Methods: Lateral headfilms from 40 White-Brazilian, 33 Japanese and 32 Japanese-Brazilian descents were selected. The three groups were composed by individuals with normal occlusion, well-balanced profiles and were separated by sex. The data were statistically analyzed with ANOVA, *t*-test, ANCOVA and MANCOVA tests.

Results: White-Brazilian males had significantly greater nasolabial angle than Japanese males. Japanese-Brazilian displayed an intermediate value between White-Brazilian and Japanese.

Conclusion: White-Brazilian, Japanese and Japanese-Brazilian present different cephalometric characteristics of McNamara analysis. Japanese males have a significantly more acute nasolabial angle than White-Brazilian subjects.

Keywords: Ethnic groups. Cephalometry. Diagnosis.

RESUMO

Introdução: A análise cefalométrica de McNamara Jr. é uma ferramenta amplamente utilizada para o diagnóstico das discrepâncias dentárias e esqueléticas, principalmente porque fornece um diagnóstico que orienta os procedimentos cirúrgicos a serem realizados ou a utilização de aparelhos funcionais. Estudos têm demonstrado que diferentes grupos étnicos apresentam padrões cefalométricos distintos. Portanto, as características próprias dos indivíduos devem ser respeitadas, para suportar o diagnóstico e facilitar o plano de tratamento, entre as diferentes etnias e seus diferentes padrões de miscigenação. **Objetivo:** Determinar os valores médios de normalidade das grandezas cefalométricas relacionadas à análise de McNamara em jovens mestiços nipo-brasileiros, com oclusão normal, descendentes de japoneses e brasileiros, e comparar os resultados das variáveis com amostras de jovens brasileiros leucodermas e xantodermas que apresentem as mesmas características. **Métodos:** Foram selecionadas 40 telerradiografias de jovens leucodermas, 33 de xantodermas e 32 de nipo-brasileiros. As três amostras foram constituídas de indivíduos com oclusão normal e face bem balanceada, e foram divididas por sexo. Os dados foram estatisticamente analisados utilizando ANOVA, teste *t*, ANCOVA e MANOVA. **Resultados:** Os leucodermas apresentaram o ângulo nasolabial significativamente maior, comparados aos japoneses, no sexo masculino; enquanto os nipo-brasileiros apresentaram um valor intermediário entre os leucodermas e xantodermas. **Conclusão:** Os grupos de leucodermas, xantodermas e nipo-brasileiros apresentaram diferentes características cefalométricas da análise de McNamara. Os xantodermas no sexo masculino tiveram o ângulo nasolabial significativamente mais agudo, quando comparados com os leucodermas.

Palavras-chave: Grupos étnicos. Cefalometria. Diagnóstico.

INTRODUCTION

In Orthodontics, several resources are available to aid diagnosis and the choice of treatment.[1-4] Lateral headfilms, for example, have been very useful in determining a more precise diagnosis, because radiograph images can now be reproduced with a minimum of distortion, facilitating orthodontic evaluation.

In 1941, Margolis[5] presented an evaluation method that allowed the study of the facial outline, the mandible and the facial bones and their relationship with the teeth before and after orthodontic treatment, using cephalometric lateral headfilms and a profile photograph. In 1943, he verified that the incisor mandibular plane angle (IMPA) had to be 90º in a pleasant skeletal pattern.[3]

Nowadays, it is known that cephalometric analysis does not serve as a fixed and unique parameter for the examination of an individual and in the determination of orthodontic diagnosis and planning.[6]

McNamara Jr. analysis is widely known among orthodontists.[7] It has some advantages over other analyzes, such as linear evaluations of apical base discrepancy and dental to apical base discrepancies. This analysis assists in the diagnosis and treatment planning of orthopedic or surgical cases.

Many of the studies on orthodontic cephalometric analyzes were based on samples of North American individuals, of essentially Anglo-Saxon origin. Thus, in view of the vast miscegenation of the world population, there is a need for research to adapt the cephalometric values found in White-Brazilians to different ethnic groups.

Population migration between different countries increases each year and, currently, Brazil is the country with the largest number of Japanese outside Japan. Based on that, it is extremely important to differentiate the variations that dento-skeletal structures may present due to the union between different ethnic groups. Because of the considerable increase of the Japanese-Brazilian population, there is a need for studies to support the diagnosis and facilitate the treatment plan for these group.

Therefore, the main purpose of this study is to compare three ethnic groups, White Brazilian, Japanese and Japanese-Brazilian, regarding the parameters of McNamara's cephalometric analysis.

MATERIAL AND METHODS

This study was approved by the Ethics in Research Committee of *Universidade de São Paulo* (USP, Brazil), under protocol number 080/2009.

The sample selection criteria included pleasing and balanced profiles with passive lip competence, facial symmetry, presence of normal occlusion or incipient Angle Class I malocclusion with normal overjet-overbite, absence or a minimal crowding of less than 2mm, presence of all permanent teeth (except the third molars), as judged using study models.

In order to confirm the absence of racial miscegenation, the grandparents and parents of the White-Brazilian and Japanese samples should not have had any miscegenation. The Japanese-Brazilian sample should be descendant of both Brazilians and Japanese, without previous miscegenation.

The White-Brazilian sample comprised 40 lateral headfilms of 20 females (mean age 13.70 ± 0.87 years) and 20 males (mean age 13.57 ± 1.03 years), from the files of the Orthodontic Department at *Faculdade de Odontologia de Bauru, Universidade de São Paulo*.

The Japanese sample consisted of 33 lateral head films of 17 females (mean age 15.65 ± 2.45 years) and 16 males (mean age 15.56 ± 2.51 years) whose parents and grandparents were born in Japan (excluding Okinawa Island).

The Japanese-Brazilian sample was constituted by 32 lateral headfilms of 17 females (mean age 13.22 ± 1.04 years) and 15 males (mean age of 14.79 ± 1.01 years). The inclusion criteria were the same as the other groups but in this case, all had to be children or grandchildren from the union of Japanese and White-Brazilians.

CEPHALOMETRIC ANALYSIS

The lateral headfilms were taken with the teeth in maximum intercuspation, in accordance with the norms of the Discipline of Radiology of the institution.

All radiographs were traced by hand on acetate paper sheets of 17.5 *x* 17.5 cm, with 0.5-mm pencil, and a semi-rigid polypropylene black molding adapted to the negatoscope with the objective of concentrating the light to promote accurate visualization of the anatomical areas of interest.

The McNamara Jr. cephalometric variables were identified according to Table 1. The variables constructed with these landmarks are illustrated and described in Figures 1 to 3.

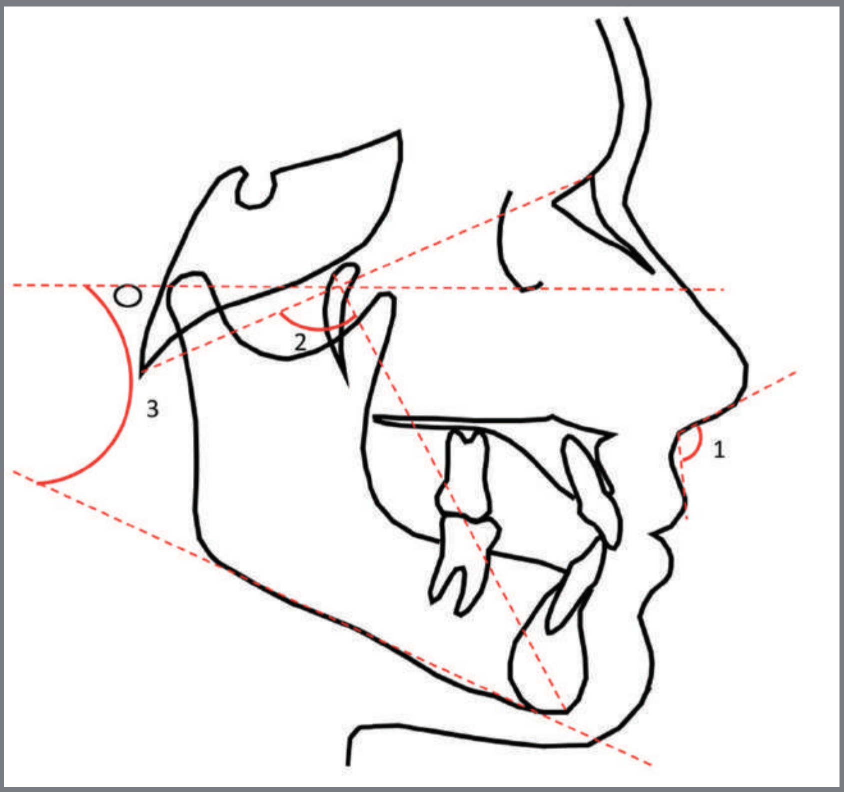

Figure 1: Angular measurements: 1) Nasolabial angle (Prn'.Sn.Ls); 2) Facial axis angle (BaN.PtGn); 3) Mandibular plane angle (PoOr.GoMe). Source: McNamara Jr,[7] 1984.

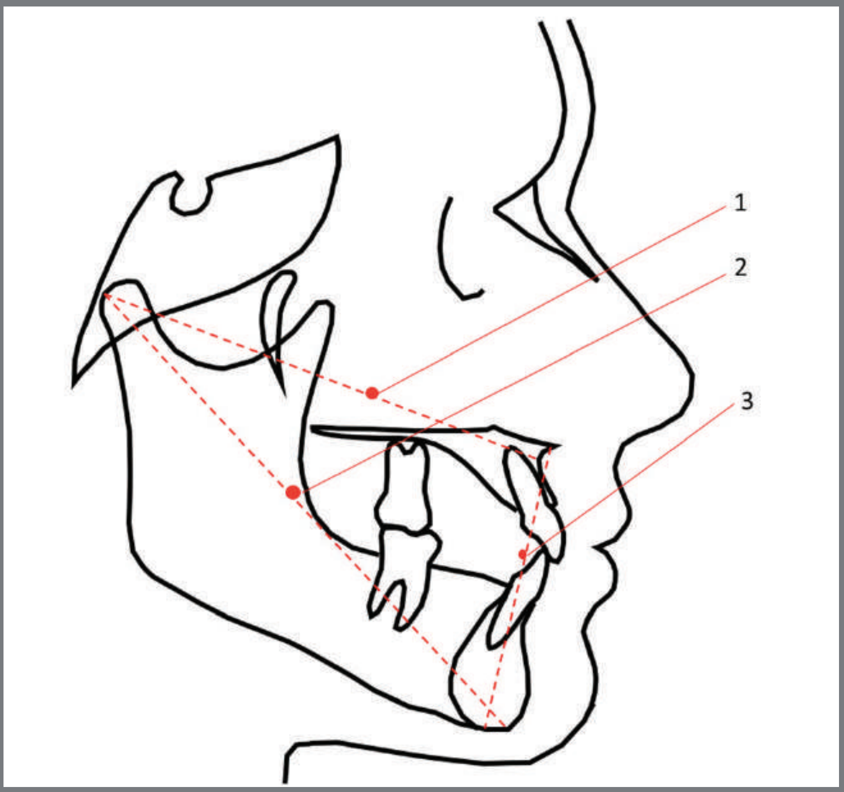

Figure 2: Reference lines and planes: 1) Midfacial length (Co-A); 2) Mandibular length (Co-Me); 3) Lower Anterior Facial Height (ANS-Me). Source: McNamara Jr,[7] 1984.

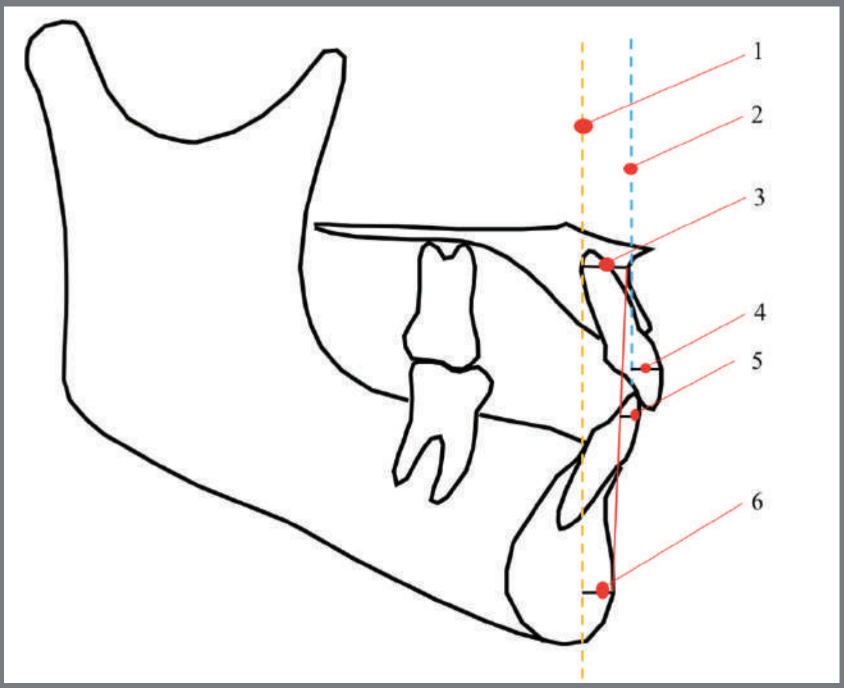

Figure 3: Reference lines: 1) Nperp, 2) Aperp, 3) A-Nperp, 4) Upper incisor to Point A vertical, 5) Lower incisor to A-Po line, 6) P-Nperp. Source: McNamara Jr,[7] 1984.

Table 1: McNamara cephalometric analysis variables.

Maxilla to cranial base	
A-Nperp	Distance between point A to Nasion perpendicular
Mandible to maxilla	
Mandibular length	Distance between Co and Gn
Midfacial length	Distance between Co and A
Maxillo-mandibular difference	Difference between the mandibular and maxillary lengths (Co-Gn) - (Co-A)
Lower Anterior Facial Height	Distance between ANS and Me
Mandibular plane angle	Angle between the anatomic Frankfurt horizontal plane and the line drawn along Go and Me (mandibular plane angle)
Facial axis angle	Angle formed by the line constructed from the pterigomaxillary fissure to Gn and the line constructed from Ba to point N
Mandible to cranial base	
P-Nperp	Distance between Pogonion and Nasion perpendicular
Dentition	
Upper incisor to Point A vertical	Distance between the facial surface of upper incisor to the perpendicular to Frankfurt plane, through point A
Lower incisor to A-Po line	Distance between the facial surface of mandibular incisor to the A-Po line
Soft tissue	
Nasolabial angle	Angle formed between lines Prn'-Sn and Sn-Ls

Subsequently, the landmarks were digitized with a Numonics, AccuGrid A30TL digitizer (Numonics Corporation, Montgomeryville, PA, USA), and stored in a computer, by a single investigator. The variables were measured with Dentofacial Planner 7.02 software (Dentofacial Planner Software Inc., Toronto, Ontario, Canada).

METHOD ERROR

In order to evaluate the method error, 30% of the sample was randomly selected and re-measured after a 30-day interval by the same investigator. To estimate the random errors, the formula proposed by Dalberg[8] ($S^2 = \Sigma d^2/2n$, where S^2 is the error variance and "d" is the difference between two determinations of the same variable) was applied. Systematic errors were evaluated with dependent *t*-tests, at $p < 0.05$.[9]

STATISTICAL ANALYSES

Normal distribution of the variables was evaluated with Kolmogorov-Smirnov tests. All variables presented normal distribution.

Sexual dimorphism within each ethnic group was evaluated with *t*-tests. Ethnic intergroup comparison within males and females was performed with ANCOVA, using the age as co-variable, followed by Tukey tests and multivariate analysis of covariance (MANCOVA).

RESULTS

The random errors ranged from 0.26mm (Lower incisor to A-Po line) to 0.74 mm (P-Nperp), and from 0.63º (Facial axis angle) to 1.6º (Nasolabial angle), and were within acceptable ranges.[10,11] There were no significant systematic errors.

The Japanese sample was significantly older than the Japanese-Brazilian sample (Table 2).

Japanese males presented significantly greater maxillary retrusion, mandibular and midfacial lengths, and maxillomandibular difference than females (Table 4).

Table 2: Intergroup age comparison between White-Brazilian, Japanese and Japanese-Brazilian and between males and females in the same ethnic group (Anova followed by Tukey tests).

	White- Brazilian		Japanese		Japanese-Brazilian		*p*
	Mean	SD	Mean	SD	Mean	SD	
Age	13.48[A]	0.89	15.30[A]	1.37	13.32[B]	1.44	0.000*
White-Brazilian							
	Females		Males				
Age	Mean	SD	Mean	SD			0.397
	13.56	0.81	13.40	0.97			
Japanese							
Age	Mean	SD	Mean	SD			0.830
	15.28	1.43	15.32	1.35			
Japanese-Brazilian							
Age	Mean	SD	Mean	SD			0.647
	13.05	1.51	13.64	1.33			

* Statistically significant at $p < 0.05$. Different superscript letters show significant differences between the means, by the Tukey test.

Table 3: White-Brazilian inter-sex comparison (*t*-tests).

White-Brazilian sample					
Variable	Female (n=20)		Male (n=20)		*p*
	Mean	SD	Mean	SD	
Maxilla to cranial base					
A-Nperp	0.24	3.57	-0.77	3.33	0.365
Mandible to maxilla					
Mandibular length (Co-Gn)	111.43	4.03	112.35	5.38	0.544
Midfacial length (Co-A)	85.53	3.22	87.00	4.45	0.237
Maxillo-mandibular difference	25.29	3.19	25.35	3.95	0.619
Lower Anterior Face Height (ANS-Me)	62.45	3.66	63.45	3.62	0.391
Mandibular plane angle (PoOr.GoMe)	24.25	4.99	26.52	3.87	0.116
Facial axis angle (BaN.PtGn)	90.41	3.07	90.98	2.35	0.514
Mandible to cranial base					
P-Nperp	-2.06	6.59	-4.49	4.59	0.185
Dentition					
Upper incisor to Point A vertical	4.24	1.62	3.65	2.20	0.340
Lower incisor to A-Po line	2.43	1.67	2.19	2.01	0.690
Soft tissue					
Nasolabial angle (Prn'.Sn.Ls)	105.71	7.46	106.72	10.56	0.727

Table 4: Japanese inter-sex comparison (*t*-tests).

Japanese sample					
Variable	Female (n=17)		Male (n=16)		*p*
	Mean	SD	Mean	SD	
Maxilla to cranial base					
A-Nperp	-0.05	2.37	-2.09	2.28	0.017*
Mandible to maxilla					
Mandibular length (Co-Gn)	110.16	3.28	115.08	4.44	0.001*
Midfacial length (Co-A)	84.08	2.90	86.54	3.64	0.039*
Maxillo-mandibular difference	26.08	2.99	28.55	3.80	0.046*
Lower Anterior Facial Height (ANS-Me)	63.27	6.55	66.36	3.90	0.112
Mandibular plane angle (PoOr.GoMe)	27.39	6.88	26.89	5.28	0.817
Facial axis angle (BaN.PtGn)	89.26	4.02	88.23	3.22	0.426
Mandible to cranial base					
P-Nperp	-6.02	6.55	-6.88	4.18	0.661
Dentition					
Upper incisor to Point A vertical	3.82	1.87	4.63	2.23	0.271
Lower incisor to A-Po line	3.68	1.77	3.52	1.57	0.781
Soft tissues					
Nasolabial angle (Prn'.Sn.Ls)	101.12	10.49	96.16	7.61	0.132

* Statistically significant at $p < 0.05$.

Japanese-Brazilian males presented significantly greater lower anterior face height and mandibular retrusion than females (Table 5).

There were significant ethnic intergroup differences among females (Table 6).

White-Brazilians had significantly greater Nasolabial angle than Japanese and significant ethnic intergroup differences among males (Table 7).

Table 5: Japanese-Brazilian inter-sex comparison (*t*-tests).

Japanese-Brazilian sample					
Variable	Female n=17		Male n=15		*p*
	Mean	SD	Mean	SD	
Maxilla to cranial base					
A-Nperp	0.86	1.88	-1.33	3.97	0.051
Mandible to maxilla					
Mandibular length (Co-Gn)	111.46	5.59	114.99	7.49	0.139
Midface length (Co-A)	84.22	3.05	86.83	5.49	0.102
Maxillo-mandibular difference	27.24	4.38	28.13	5.18	0.601
Lower Anterior Facial Height (ANS-Me)	62.36	2.58	66.89	5.10	0.003*
Mandibular plane angle (PoOr.GoMe)	23.85	3.00	27.16	6.11	0.057
Facial axis angle (BaN.PtGn)	91.10	2.53	88.93	4.54	0.099
Mandible to cranial base					
P-Nperp	-0.58	4.39	-6.05	6.95	0.011*
Dentition					
Upper incisor to Point A vertical	5.36	2.23	4.77	2.29	0.466
Lower incisor to A-Po line	2.89	2.20	3.66	2.49	0.363
Soft tissues					
Nasolabial angle (Prn'.Sn.Ls)	99.69	9.28	102.56	12.16	0.456

* Statistically significant $p < 0.05$.

Table 6: Female intergroup comparisons (ANCOVA and Multivariate Test of Significance).

Variable	White-Brazilians (n=20)		Japanese (n=17)		Japanese-Brazilians (n=17)		*p*	*p*
	Mean	SD	Mean	SD	Mean	SD		
Maxilla to cranial base								
A-Nperp	0.24	3.57	-0.05	2.36	0.86	1.88	0.762	
Mandible to maxilla								
Mandibular length (Co-Gn)	111.43	4.03	110.16	3.28	111.46	5.59	0.073	
Midface length (Co-A)	85.53	3.22	84.08	2.90	84.22	3.05	0.148	
Maxillo-mandibular difference	25.92	3.19	26.08	2.99	27.24	4.38	0.165	
Lower Anterior Facial Height (ANS-Me)	62.45	3.66	63.27	6.55	62.36	2.58	0.728	
Mandibular plane angle (PoOr.GoMe)	24.25	4.99	27.39	6.88	23.85	3.00	0.170	0.009†
Facial axis angle (BaN.PtGn)	90.41	3.08	89.26	4.02	91.11	2.53	0.622	
Mandible to cranial base								
P-Nperp	-2.06	6.59	-6.02	6.55	-0.58	4.39	0.059	
Dentition								
Upper incisor to Point A vertical	4.24	1.62	3.82	1.87	5.36	2.23	0.183	
Lower incisor to A-Po line	2.43	1.67	3.68	1.77	2.89	2.20	0.080	
Soft tissues								
Nasolabial angle (Prn'.Sn.Ls)	105.71	7.46	101.12	10.49	99.69	9.28	0.074	

† Statistically significant at $p < 0.05$ based on MANCOVA test.

Table 7: Male intergroup comparisons (ANCOVA followed by Tukey tests and Multivariate Test of Significance).

Variable	White-Brazilian (n=20)		Japanese (n=15)		Japanese-Brazilian (n=16)		*p*	*p*
	Mean	SD	Mean	SD	Mean	SD		
Maxilla to cranial base								
A-Nperp	-2.09	2.28	-0.77	3.33	-1.33	3.97	0.802	
Mandible to maxilla								
Mandibular length (Co-Gn)	112.35	5.38	115.08	4.44	114.99	7.49	0.786	
Midface length (Co-A)	87.00	4.45	86.54	3.64	86.83	5.49	0.764	
Maxillo-mandibular difference	25.35	3.95	28.55	3.80	28.13	5.18	0.336	
Lower Anterior Facial Height (ANS-Me)	63.45	3.62	66.36	3.90	66.89	5.10	0.195	
Mandibular plane angle (PoOr.GoMe)	26.52	3.87	26.89	5.28	27.16	6.11	0.927	0.049†
Facial axis angle (BaN.PtGn)	90.98	2.35	88.23	3.22	88.93	4.54	0.075	
Mandible to cranial base								
P-Nperp	-4.49	4.59	-6.88	4.18	-6.05	6.95	0.543	
Dentition								
Upper incisor to Point A vertical	3.65	2.20	4.63	2.23	4.77	2.29	0.311	
Lower incisor to A-Po line	2.19	2.01	3.52	1.57	3.66	2.49	0.111	
Soft tissues								
Nasolabial angle (Prn'.Sn.Ls)	106.72^{A}	10.56	96.16^{B}	7.61	$102.56^{A,B}$	12.16	0.026*	

* Statistically significant at $p<0.05$ based on ANCOVA test. † Statistically significant at $p<0.05$ based on MANCOVA test. Different superscript letters show significant differences between the means by the Tukey test.

DISCUSSION

SAMPLE

Study samples have widely varied in the number of subjects, such as that of Cotton, Takano and Wong,[12] who used a sample of only 20 individuals, and Shishikura,[13] who used 132 individuals. Although the Japanese sample had a mean age significantly greater than the White-Brazilian and Japanese-Brazilian samples, in order to obtain a sample with the highest possible number of individuals, statistics was adjusted for the comparison between the three groups, in order to establish if the age would present any influence on the cephalometric measurements of the ethnic group.

Differences were found between male and female in the literature and in the present study.[11,14,15] For this reason, the ethnic group comparisons had to be separated by sex.

SEX DIFFERENCE

In the White-Brazilian sample, no significant differences between males and females were found (Table 3). Nevertheless, males presented higher values, compared to females. Similar findings were reported by Miyajima et al.,[16] indicating that the dentoskeletal variables in males and females with ideal occlusion tend to be larger in males.

There was significantly greater retrusion of the maxilla in males than in females in the Japanese sample (Table 4). These characteristics of the skeletal tissues were confirmed by previous research.[17] The midfacial length (Co-A), mandibular length (Co-Gn) and the maxillo-mandibular difference were significantly larger in males than in females. Similar findings were reported by Miyajima et al.[16] and Bronfman et al.,[18] who noticed significant sexual dimorphism in the midface and in mandibular length. Because the midface and the mandibular length were larger, the maxillo-mandibular difference was also larger in males than in females.

The Japanese-Brazilian sample presented dimorphism for some skeletal variables, with the highest values found for males (Table 5). Males displayed significantly greater anterior facial height than females. Supporting the results obtained by Ioi et al.,[19] who concluded that Japanese males have significantly longer faces than Japanese females. Also, males showed the mandible statistically more retruded than females. Similar values were obtained in the literature by Alcalde et al.[17]

ETHNIC DIFFERENCES

The samples were separated by sex to obtain a more specific and useful cephalometric normative values of each ethnic group.[16,17,20-22]

In males and females, the lower anterior face height was not significantly different between the three samples, which corroborates with the results of Nezu et al.[23] and Alcalde et al.[17] (Tables 6 and 7).

No significant differences in the dentition variables between the three samples could be noticed (Tables 6 and 7). The results found by Sathler et al.[24] also demonstrated no differences in the upper incisor position between the Japanese-Brazilian and Caucasian sample. However, findings of Miura et al.,[25] Miyajima et al.,[16] and Ioi et al.[19] found that Japanese-Brazilians have greater protrusion of the mandibular incisors.

Among the studied samples, only the nasolabial angle in males was significantly more acute in Japanese than in White-Brazilian (Table 7). The Japanese-Brazilian presented an average value intermediate to the group of White-Brazilian and Japanese. These results coincide with Bronfman et al.[18] and Miyajima et al.,[16] that also observed a more acute nasolabial angle in Japanese.

McNamara Jr.[7] reports that separate evaluation of soft and skeletal tissues usually leads to the same diagnosis, so a patient with an acute nasolabial angle also has a protruded maxila. In this study, the male Japanese group that presented more acute nasolabial angle also had the greatest maxillary protrusion, which has been previously observed.[24] In addittion, Miyajima et al.[16] concluded that Japanese presents greater lip protrusion.

Results showed significant differences between White-Brazilian, Japanese and Japanese-Brazilian using MANCOVA test (Tables 6 and 7). This test compares the three ethnic groups comparing all the variables together, in order to find differences between them. Previous studies found differences between Caucasians and Japanese sample[16,18,24,25] that confirm the present findings. Therefore, the orthodontist must be careful and individualize each ethnic group during diagnosis and treatment planning.[26,27]

CONCLUSIONS

» White-Brazilian, Japanese and Japanese-Brazilian have, in general, similar cephalometric characteristics of McNamara Jr. analysis.

» Japanese males have a significantly more acute nasolabial angle than White-Brazilian subjects.

» The findings of these study support that one cephalometric parameter is not appropriate to application in different ethnic groups because of the intergroups differences observed.

AUTHORS' CONTRIBUTION

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REFERENCES

1. Burstone C. The integumental profile. Am J Orthod. 1958;44(1):1-25.
2. Stoner M. A photometric analysis of the facial profile. Am J Orthod. 1955;41(6):453-69.
3. Margolis H. The axial inclination of the mandibular incisors. Am J Orthod Oral Surg. 1943;29(10):571-94.
4. Albino JE, Tedesco LA. Esthetic need for orthodontic treatment. In: Melsen B, editor. Current Controversies in orthodontics. Chicago, IL: Quintessence, 1991. p. 11-24.
5. Margolis H. Composite x-ray photographs. Am J Orthod Oral Surg. 1941;27(12):717-22.
6. Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning--Part II. Am J Orthod Dentofacial Orthop. 1993;103(5):395-411.
7. McNamara Jr. JA. A method of cephalometric evaluation. Am J Orthod. 1984;86(6):449-69.
8. Dahlberg G. Statistical methods for medical and biological students. Br Med J. 1940;2(4158):358-9.
9. Houston WJ. The analysis of errors in orthodontic measurements. Am J Orthod. 1983;83(5):382-90.
10. Midtgard J, Bjork G, Linder-Aronson S. Reproducibility of cephalometric landmarks and errors of measurements of cephalometric cranial distances. Angle Orthod. 1974;44:56-61.

11. Wu J, Hagg U, Rabie AB. Chinese norms of McNamara's cephalometric analysis. Angle Orthod. 2007;77(1):12-20.

12. Cotton WN, Takano WS, Wong WM. The Downs analysis applied to three other ethnic groups. Angle Orthod. 1951;21(4):213-20.

13. Shishikura K. [The study on measurements of hard and soft tissues by cephalograms--particularly on normal and Class I occlusion among Japanese adults]. Nihon Kyosei Shika Gakkai Zasshi. 1969;28:263-73.

14. Huang WJ, Taylor RW, Dasanayake AP. Determining cephalometric norms for Caucasians and African Americans in Birmingham. Angle Orthod. 1998;68(6):503-11.

15. Lee JJ, Ramirez SG, Will MJ. Gender and racial variations in cephalometric analysis. Otolaryngol Head Neck Surg. 1997;117(4):326-9.

16. Miyajima K, McNamara Jr. JA, Kimura T, Murata S, Iizuka T. Craniofacial structure of Japanese and European-American adults with normal occlusions and well-balanced faces. Am J Orthod Dentofacial Orthop. 1996;110(4):431-8.

17. Alcalde RE, Jinno T, Pogrel MA, Matsumura T. Cephalometric norms in Japanese adults. J Oral Maxillofac Surg. 1998;56(2):129-34.

18. Bronfman CN, Janson G, Pinzan A, Rocha TL. Cephalometric norms and esthetic profile preference for the Japanese: a systematic review. Dental Press J Orthod. 2015;20(6):43-51.

19. Ioi H, Nakata S, Nakasima A, Counts AL. Comparison of cephalometric norms between Japanese and Caucasian adults in antero-posterior and vertical dimension. Eur J Orthod. 2007;29:493-9.

20. Qamruddin I, Alam MK, Shahid F, Tanveer S, Mukhtiar M, Asim Z. Assessment of gender dimorphism on sagittal cephalometry in Pakistani population. J Coll Physicians Surg Pak. 2016;26(5):390-3.

21. Todorova-Plachiyska KG, Stoilova-Todorova MG. Lateral Cephalometric Study in Adult Bulgarians with Normal Occlusion. Folia Med (Plovdiv) 2018;60(1):141-6.

22. Scavone Jr. H, Trevisan Jr. H, Garib DG, Ferreira FV. Facial profile evaluation in Japanese-Brazilian adults with normal occlusions and well-balanced faces. Am J Orthod Dentofacial Orthop. 2006;129(6):721.e1-5.

23. Nezu H, Nagata K, Yoshida Y, Kosaka H, Kikuchi M. Cephalometric comparison of clinical norms between the Japanese and Caucasians. Nihon Kyosei Shika Gakkai Zasshi. 1982;41(3):450-65.

24. Sathler R, Pinzan A, Fernandes TM, Almeida RR, Henriques JF. Comparative study of dental cephalometric patterns of Japanese-Brazilian, Caucasian and mongoloid patients. Dental Press J Orthod. 2014;19(4):50-7.

25. Miura F, Inoue N, Suzuki K. Cephalometric standards for Japanese according to the Steiner analysis. Am J Orthod. 1965;51:288-95.

26. Tweed C. Indications for the extraction of teeth in orthodontic procedure. Am J Orthod. Oral Surg. 1944;30(8):405-28.

27. Downs W. Variations in facial relationships: their significance in treatment and prognosis. Am J Orthod. 1948;34(10):812-40.

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Influence of radiant exposure values from two third generation LED curing units on polymerization profile and microhardness of orthodontic composite under ceramic and metallic brackets

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ABSTRACT

Introduction: Third generation of LED light curing units might be used in short exposure periods for orthodontic brackets bonding.

Objective: This study evaluated the effect of the different radiant exposure (RE) values: Manufacturers' instructions (MI), ½ MI, 1/4 MI and Turbo mode. Two third-generation LED curing units were used: VALO® and Bluephase 20i® . The degree of conversion (DC) and Vickers hardness (VHN) of an orthodontic composite (OC) (Transbond XT) under metallic (MB) or ceramic brackets (CB) were measured.

Methods: OC was applied to the bracket base, which was then placed over an attenuated total reflectance (ATR) table coupled to an infrared light spectroscope, or to a glass surface for the VHN analysis. The specimens were light-cured and DC values were calculated. The VHN was obtained in a microhardness tester. The data were analyzed with 2-way ANOVA followed by Tukey's *post-hoc* test (pre-set α=0.05). Linear regression analysis evaluated the relationship between RE values and dependent variables.

Results: CB allowed higher DC and VHN values than MB ($p < 0.001$). No significant difference was noted among groups when CB were used. For MB, MI groups showed the highest DC and VHN values. A significant, but weak relationship was found between delivered RE values and dependent variables.

Conclusions: The decrease in RE values from third generation LED CU did not jeopardize the DC values when CB were used, but can compromise DC and VHN values when MB are used.

Keywords: Curing lights. Hardness. Orthodontic bracket. Polymerization.

RESUMO

Introdução: A terceira geração de LEDs fotopolimerizadores pode ser utilizada em curtos períodos de exposição para a colagem de braquetes ortodônticos. **Objetivo:** O presente estudo avaliou o efeito dos diferentes valores de irradiância (IR): instruções do fabricante (IF), ½ IF, ¼ IF e modo Turbo. Dois fotopolimerizadores LED de terceira geração (VALO® e Bluephase20i®) foram utilizados. Foram mensurados o grau de conversão (GC) e a dureza Vickers (VHN) de um compósito ortodôntico (CO) (Transbond XT) sob braquetes metálicos (BM) ou cerâmicos (BC). **Métodos:** O compósito ortodôntico foi aplicado na base do braquete e foi posicionado sobre uma mesa de refletância total atenuada (ATR) acoplada a um espectroscópio de infravermelho ou a uma superfície de vidro para análise de VHN. As amostras foram fotopolimerizadas e os valores de GC foram calculados. O VHN foi obtido em um microdurômetro. Os dados foram analisados com ANOVA de 2 fatores seguida do teste *post-hoc* de Tukey (predefinido $\alpha = 0,05$). A análise de regressão linear avaliou a relação entre os valores de IR e as variáveis dependentes. **Resultados:** BC permitiu valores maiores de GC e VHN do que BM ($p<0,001$). Nenhuma diferença significativa foi observada entre os grupos quando BC foi utilizado. Para BM, os grupos de IF mostraram os maiores valores de GC e VHN. Uma relação significativa, mas fraca, entre os valores de IR entregue e as variáveis dependentes foi encontrada. **Conclusões:** A diminuição dos valores de IR dos fotopolimerizadores LED de terceira geração não prejudicou os valores de GC quando BC foram utilizados, mas pode comprometer os valores de GC e VHN quando BM são utilizados.

Palavras-chave: Fotopolimerizadores. Dureza. Braquete ortodôntico. Polimerização.

INTRODUCTION

The treatment success with fixed orthodontic appliance depends substantially on the accurate bracket bonding to enamel surface. The "adhesive" dentistry became viable after the introduction of the enamel etching with phosphoric acid, by Buonocore,[1] and the release of resin composites. In Orthodontics, this advance allowed predictable direct bonding of brackets to enamel surface.[2]

Different types of orthodontic composites (OC) have been used in clinical practice. Some are light-cured materials, others are self-cured resins, and there are also dual-cured OCs, which have both photoinitiators and self-curing components in their composition.[3] Although these products have shown acceptable mechanical proprieties,[4] the use of light-curing units (LCU) is required regardless of the OC type, to ensure that brackets are bonded without wasting chairtime, once photo-activated polymerization is considerably faster than self-cured polymerization.[5,6] Indeed, in order to provide optimal degree of conversion (DC) and mechanical properties of OCs, the radiant emittance values must be considerably high.[7] In this regard, recently, third generation light-emitting diode (LEDs) curing units have become available for dental practitioners.[8] Also known as multi-peak LCUs, these LED devices are capable of emitting light with varying wavelength ranging from 390 nm to 490 nm.[8,9]

The polymerization efficiency of OCs depends on the radiant emittance values, exposure time, and the light source. In general, the physical and mechanical properties of resin-based materials are closely related to the DC.[10,11] In addition, poor monomer conversion results in monomer leaching and the release of plasticizers and polymerization initiators.[12,13] Such an issue is a matter of concern as monomer leaching from poorly polymerized resin-based composites has been associated with metabolic diseases, problems in gene expression,[14] and also problems in immune responses.[15]

Despite the advances in adhesion and LED technology, the currently used bonding protocol for metallic and ceramic brackets still remains a time-consuming procedure, once clinicians usually avoid short exposure intervals. Longer chairtime also increases the chance of bonding failures due to contamination, mainly in posterior and lower teeth.[16] In this regard, some *in vitro* studies have evaluated the influence of LCU types and shorter exposure periods of LCU on monomer conversion of OCs.[17] Although most studies properly addressed this issue and observed the influence of exposure period and LCU type, the differences in products and curing protocols among studies resulted in controversial findings. In addition, none of these studies evaluated the influence of both metallic and ceramic brackets interposed between the LCU tip and the OC layer on DC values and kinetics of polymerization. To date, no information is available in the literature regarding the use of powerful third generation LED CUs at short exposure periods on OC polymerization.

Thus, this study evaluated the effects of varying radiant exposure (RE) values comprising short exposure intervals to light emitted from two high power LED CUs on DC, maximum rate of polymerization (Rp_{max}) and Vickers hardness (VHN) of one commercially available OC in a clinical simulated bonding procedure of metallic or ceramic brackets. The research hypotheses were: (1) the delivery of lower RE values decreases DC, Rp_{max}, and VHN values of OC layers after exposure to light emitted from polywave LED CU through either metallic or ceramic brackets; (2) there is direct and positive relationship between RE values and DC or VHN values; and (3) the DC, Rp_{max}, and VHN values after LED exposure through ceramic brackets are higher than those observed after exposure through metallic brackets.

MATERIAL AND METHODS

ANALYSIS OF THE DEGREE OF CONVERSION

A commercially available OC (Transbond™ XT, 3M, California, USA) was used in the present research. The metallic and ceramic brackets (Roth prescription, Morelli, Sorocaba/SP, Brazil) were employed for the tests. The third generation LED CUs (VALO®, Ultradent Products Inc, South Jordan, UT, USA; and Bluephase 20i®, Ivoclar Vivadent Inc., Ivoclar Vivadent, Schaan, Liechtenstein) were evaluated. Radiant emittance values of light emitted by the LED CUs were measured with a portable laser power meter (407A, Newport Corporation, CA, USA). In order to simulate a clinical situation, the OC was applied to the orthodontic bracket according to the manufacturer's instructions. The orthodontic bracket containing the OC layer was placed on the diamond surface of an attenuated total reflectance (ATR) table (Satandard Golden Gate, Specac, Woodstock, GA, USA) coupled to an infrared light spectroscope (FTIR, Tensor 27, Bruker Optik GmbH, Ettlingen, Germany), so the OC layer was in contact with both ATR diamond surface and the bracket base. The LCU tip was placed against the bracket and the specimens were exposed to light emitted either from VALO or Bluephase20i at the following exposure intervals and exposure modes: Manufacturers' instructions (MI), half MI, one quarter MI and Turbo mode, in which the RE values were delivered at shorter exposure periods and higher radiant emittance than that of MI or half MI, as shown in Table 1. Therefore, the RE values delivered to the specimens ranged from 6 J/cm^2 to 22.9 J/cm^2 when metallic brackets were used, and from 2.85 J/cm^2 to 11.4 J/cm^2 when ceramic brackets were used (Table 1). In addition, in an attempt to simulate the clinical scenario where LCU tip is placed on the mesial and distal portion of the metallic bracket, the LCU tip was placed in two directions, so light was delivered for half exposure period in each side. Conversely, when ceramic brackets were used, the LCU tip was placed directly against the ceramic bracket. Seven specimens were evaluated for each experimental group (n=7).

Table 1: Experimental groups evaluated in the study.

LED LCU	Bracket	Exposure mode	Radiant emittance (mW/cm²)	Exposure period (s)	Radiant Exposure values (J/cm²)	Group name	Description
Valo	Metallic	Standard power	1273	18	22.9	MI	Control
				9	11.5	½ MI	Half control time
				5	6.4	¼ MI	Quarter control time
		Plasma Emulation	3200	6.6	21.1	Turbo	Plasma
	Ceramic	Standard power	1273	9	11.5	MI	Control
				4.5	5.7	½ MI	Half control time
				2.25	2.9	¼ MI	Quarter control time
		Plasma Emulation	3200	3.33	10.7	Turbo	Plasma
Bluephase	Metallic	Standard power	1136	20	22.7	MI	Control
				10	11.36	½ MI	Half control time
				5	5.68	¼ MI	Quarter control time
		Turbo	2045	6	12.3	Turbo	Turbo
	Ceramic	Standard power	1136	10	11.36	MI	Control
				5	5.68	½ MI	Half control time
				2.5	2.84	¼ MI	Quarter control time
		Turbo	2045	3	6.12	Turbo	Turbo

Infrared spectra were collected between 1680 and 1500 cm^{-1} at a rate of one spectrum per second (16 scans/spectrum) at 4 cm^{-1} resolution. Data were collected from the moment the infrared scan demonstrated that the resin was stabilized on the ATR surface and the bracket had been placed. Spectra were recorded continuously during each 1-second interval for 10 minutes.

DC values were calculated using standard methods that evaluated changes in the ratios of aliphatic-to-aromatic C=C absorption peaks (1636 cm^{-1}/1608 cm^{-1}) in the uncured and cured states obtained from the infrared spectra.[18] Rp_{max} values corresponded to the highest rate of polymerization (percentage) and were calculated based on the differences between DC values measured in sequential, 1-second intervals throughout the 10-min analysis of each specimen.

DC equation:

$$DC = \underline{1} - \frac{[abs\ (C{=}C\ alifatic)/abs\ (C...C\ aromatic)]\ polymer}{[abs\ (C = C\ alifatic)/abs\ (C...C\ aromatic)]\ monomer}\ x\ 100$$

DC: Degree Conversion (%)

abs: absorbance

MICROHARDNESS TEST

For VHN, 80 metallic and ceramic brackets were used. Prior to OC placement, both brackets had the rough back-surface smoothed to remove any retention, so the OC could be removed and the bracket could be reused. The OC was applied to the bracket according to MI, and the set orthodontic bracket/composite layer was placed on a glass surface. The LCU tip was placed on the bracket and the specimens were exposed to the LED CUs at varying exposure intervals, as previously describe.

Hardness was immediately evaluated with microhardness indenter (Microhardness tester- Shimadzu Corporation, Kyoto, Japan). VHN analysis was performed as reported by Garcia-Contreras et al.[19] A diamond indenter was applied to the OC surface at 5 N or 50 Kgf, and a 15-s indentation interval was used. Five indentations were obtained on each corner, resulting in a total of 20 indentations in each specimen (Fig 1).

STATISTICAL ANALYSIS

Because light beam profiles of the evaluated LCUs were not similar, no comparison between results of each tested LCU was made. Therefore, the DC, VHN and Rpmax (%/s) values were evaluated using 2-way ANOVA ("exposure mode" and "bracket type" as independent variables) within each LCU, followed by Tukey's *post-hoc* test at a pre-set alpha of 5%.

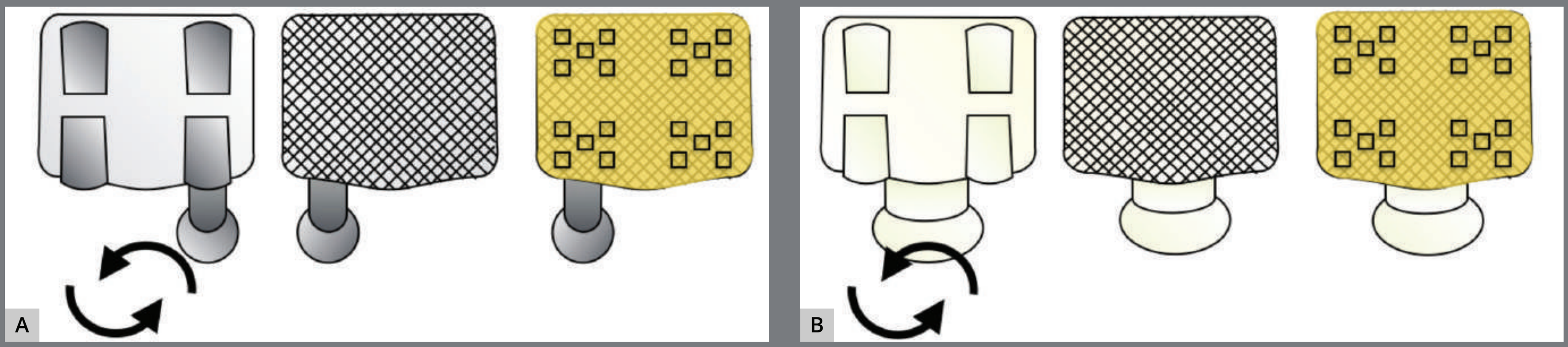

Figure 1: Illustrative image of OC layer on metallic (A) and ceramic (B) brackets and all indentations made in each corner.

Linear regression analysis was performed to evaluate the relationship between RE values and either DC or VHN values. *Post-hoc* power analysis was performed for the statistical analyses of DC, Rp_{max}, and VHN values. All statistical analyses were performed using statistical softwares (Prism for Macintosh version 6.0, GraphPad Software Inc., CA, USA, and Statistics 19, SPSS Inc, IBM Company).

RESULTS

DEGREE OF CONVERSION (DC) AND RP_{MAX} VALUES

The DC (%) and Rp_{max} (%/s) values after exposure to VALO or Bluephase20i at varying RE values (J/cm^2) are shown in Tables 2 and 3, respectively. Two-way ANOVA detected statistical significance for the independent variable "exposure mode" and "bracket type" (p<0.001), as well as for the statistical interaction between the independent variables (p<0.001), regardless of LCU type, for both DC and Rp_{max} values.

Overall, the use of ceramic bracket resulted in higher DC and Rp_{max} values than the use of metallic bracket either when VALO or Bluephase20i were used. For both LCUs, no significant difference was noted among groups when ceramic brackets were used. However, within the group comprising the use of metallic brackets after exposure to VALO, the MI and Turbo groups showed the highest DC values. The DC values observed in 1/2-MI group were significantly lower than those of MI group (p<0.001) but not significantly different from those of Turbo group. The 1/4-MI group showed the lowest DC values (p<0.001), which were not significantly lower than those observed in 1/2-MI group. Within the groups comprising the use of metallic brackets after exposure to Bluephase20i, the MI group showed the highest DC values, which were significantly higher than those observed in the other groups (p<0.001). No significant difference in DC values was noted among the other groups.

Table 2: Mean (SD) DC values after exposure to light emitted from LCUs at varying radiant exposure values under metallic and ceramic brackets.

	Irradiation	Metallic	Ceramic
VALO	MI	35.8 (3.4)^{Ab}	47.0 (1.6)^{Aa}
	½ MI	27.0 (4.4)^{BCb}	44.7 (1.4)^{Aa}
	¼ MI	21.6 (6.9)^{Cb}	43.0 (1.9)^{Aa}
	Turbo MI	31.6 (5.4) ^{ABb}	44.4 (1.5)^{Aa}
Bluephase20i	MI	35.0 (3.5) ^{Ab}	45.6 (1.4)^{Aa}
	½ MI	28.0 (3.1)^{Bb}	43.6 (1.2)^{Aa}
	¼ MI	23.7 (6.1)^{Bb}	44.0 (2.3)^{Aa}
	Turbo MI	28.2 (5.8)^{Bb}	46.2 (2.0)^{Aa}

* Significant differences between means are followed by different superscript letters (uppercase within column; lower case within row, pre-set alpha of 0.05). No comparison between results of different LCUs was performed.

Table 3: Mean (SD) Rpmax values after exposure to light emitted from VALO and Bluephase 20i at varying radiant exposure values under metallic and ceramic brackets.

	Irradiation	Metallic	Ceramic
VALO	MI	2.7 (1.1)^{Ab}	10.9 (1.5)^{Ba}
	½ MI	2.4 (0.8)^{Ab}	10.6 (1.0)^{Ba}
	¼ MI	2.8 (1.0)^{Ab}	11.0 (1.3)^{Ba}
	Turbo MI	3.9 (1.8)^{Ab}	14.0 (1.5)^{Aa}
Bluephase20i	MI	2.6 (1.1)^{Ab}	10.5 (1.6)^{Ba}
	½ MI	2.4 (0.8)^{Ab}	10.3 (1.2)^{Ba}
	¼ MI	3.1 (1.2)^{Ab}	11.2 (1.3)^{Ba}
	Turbo MI	2.9 (0.8)^{Ab}	14.0 (1.5)^{Aa}

* Significant differences between means are followed by different superscript letters (uppercase within column; lower case within row, pre-set alpha of 0.05). No comparison between results of different LCUs was performed

When orthodontic composite was exposed to light emitted from VALO or Bluephase20i placed over ceramic brackets, Turbo groups exhibited the highest Rp_{max} values (p<0.001). No significant difference was observed among the other groups, all of which showed significantly lower Rp_{max} values than did the Turbo groups (p<0.001). When metallic brackets were used, no significant difference in the Rp_{max} values was noted among groups, regardless of LCU type.

Figure 2 shows representative real-time profiles of kinetics of polymerization during exposure to light emitted from either VALO or Bluephase20i, when metallic or ceramic brackets were used. When ceramic brackets were used, similar real-time profiles were observed for all exposure modes, regardless of LED CU. Fast rise in DC values were noted during exposure to

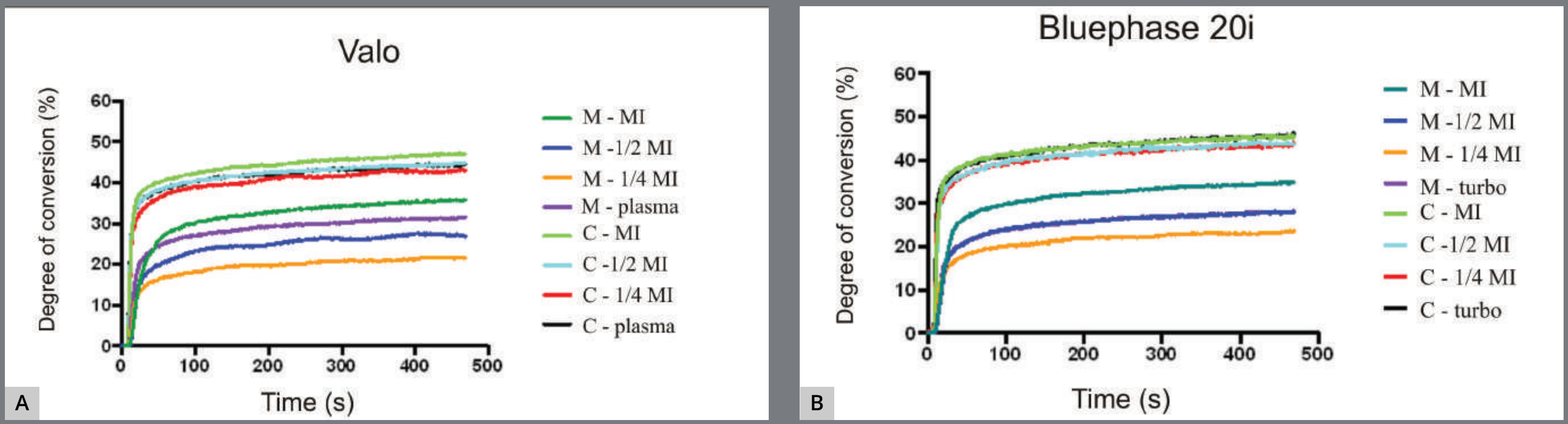

Figure 2: Representative real-time kinetic profile of monomer conversion of OC layer at varying exposure conditions under either metallic (M) or ceramic (C) brackets, during exposure to light emitted from VALO or Bluephase20i.

LCU light, then the rate of monomer conversion decreased when DC values reached approximately 38% to 40%, corresponding to polymer vitrification. Slow increase in DC values was noted after that period.

Conversely, when metallic brackets were used, real-time profile of kinetics of polymerization was clearly affected by the exposure mode, regardless of LED CU. More specifically, the fast rise in monomer conversion was shorter when shorter exposure modes were used, in comparison to those observed for longer exposure modes. Therefore, when shorter exposure modes were used, the rate of monomer conversion slowed down at apparently lower DC values (ranging from approximately 15% to 25%) than those observed when longer exposure modes were delivered to the orthodontic composite. As a consequence, lower 10-min DC was noted after shorter exposure modes. The exception was noted when shorter exposures at high intensity were used (Plasma mode in VALO and Turbo mode in BLuephase20i). Despite the short exposure periods in those exposure modes, the resulting real-time profile of kinetics of polymerization was close to that observed when the orthodontic composite was exposed to LCU light following MI.

VICKERS MICROHARDNESS

The VHN values (Vickers) and standard deviation (SD) after exposure to VALO or Bluephase20i at varying RE values (J/cm^2) are shown in Table 4. Two-way ANOVA detected statistical significance for the interaction between independent variables "exposure mode" and "bracket type", regardless of LCU (p<0.001).

When the OC layer having metallic bracket was exposed to light emitted from VALO, MI group exhibited the highest VHN values, which were significantly higher than those of the other groups (p<0.001). No significant difference in VHN values was observed between 1/2-MI and Turbo groups, which in turn

Table 4: Mean (SD) VHN values after exposure to light emitted from the LCUs at varying radiant exposure values under metallic and ceramic brackets.

	Irradiation	Metallic	Ceramic
VALO	MI	42.4 (1.4)^{Aa}	41.8 (2.1)^{Aa}
	½ MI	32.7 (1.6)^{Bb}	37.3 (2.2)^{Ba}
	¼ MI	21.1 (1.0)^{Cb}	30.0 (1.0)^{Ca}
	Turbo MI	31.3 (1.8)^{Bb}	35.7 (0.6)^{Ba}
Bluephase20i	MI	40.1 (1.4)^{Aa}	41.4 (1.1)^{Aa}
	½ MI	29.7 (1.4)^{Cb}	39.0 (1.3)^{Ba}
	¼ MI	19.3 (1.5)^{Db}	30.4 (1.4)^{Da}
	Turbo MI	32.1 (1.3)^{Bb}	36.1 (1.5)^{Ca}

* Significant differences between means are followed by different superscript letters (uppercase within column; lower case within row, pre-set alpha of 0.05). No comparison between results of different LCUs was performed.

showed higher VHN values than did 1/4-MI group (p<0.001). The exposure to curing light through ceramic brackets resulted in significantly higher VHN values than the exposure through metallic brackets in most groups (p<0.001). The only exception was observed in MI groups, where no significant difference was noted between those groups having metallic brackets and those having ceramic brackets.

When Bluephase20i was used, the exposure following MI instructions resulted in the highest VHN values, regardless of the bracket type. When the metallic brackets were used, Turbo MI groups promoted higher VHN values than did 1/2-MI (p<0.001), which in turn exhibited significantly higher VHN values than did 1/4-MI group (p<0.001). Similarly to the results obtained with VALO, exposure to light from Bluephase20i through ceramic bracket promoted higher VHN values than the exposure through metallic bracket in most groups, with the exception of MI group, in which no significant difference was observed in VHN values when ceramic brackets were used, in comparison to the values observed when metallic brackets were used.

LINEAR REGRESSION ANALYSIS

Figures 3 and 4 show the results of linear regression analysis of the relationship between RE values and both DC and VHN values, respectively. When metallic brackets were used, a significant, weak positive relationship was observed between applied RE values and either DC or VHN values after exposure to light emitted from VALO ($r^2 = 0.510$; $p<0.001$ for DC values; $r^2 = 0.210$; $p=0.003$ for VHN values) and Bluephase20i ($r^2 = 0.440$; $P<0.001$ for DC values; $r^2 = 0.626$; $p<0.001$ for VHN values). Weaker relationship between RE values and DC or VHN values was observed when ceramic brackets were used, either when light was emitted from VALO ($r^2=0.283$; $p<0.001$ for DC values; $r^2 = 0.189$; $p<0.005$) or when light was emitted from Bluephase20i regarding VHN values ($r^2=0.317$; $p<0.001$). The relationship between RE values and DC values was not statistically significant when Bluephase20i was used ($p=0.063$).

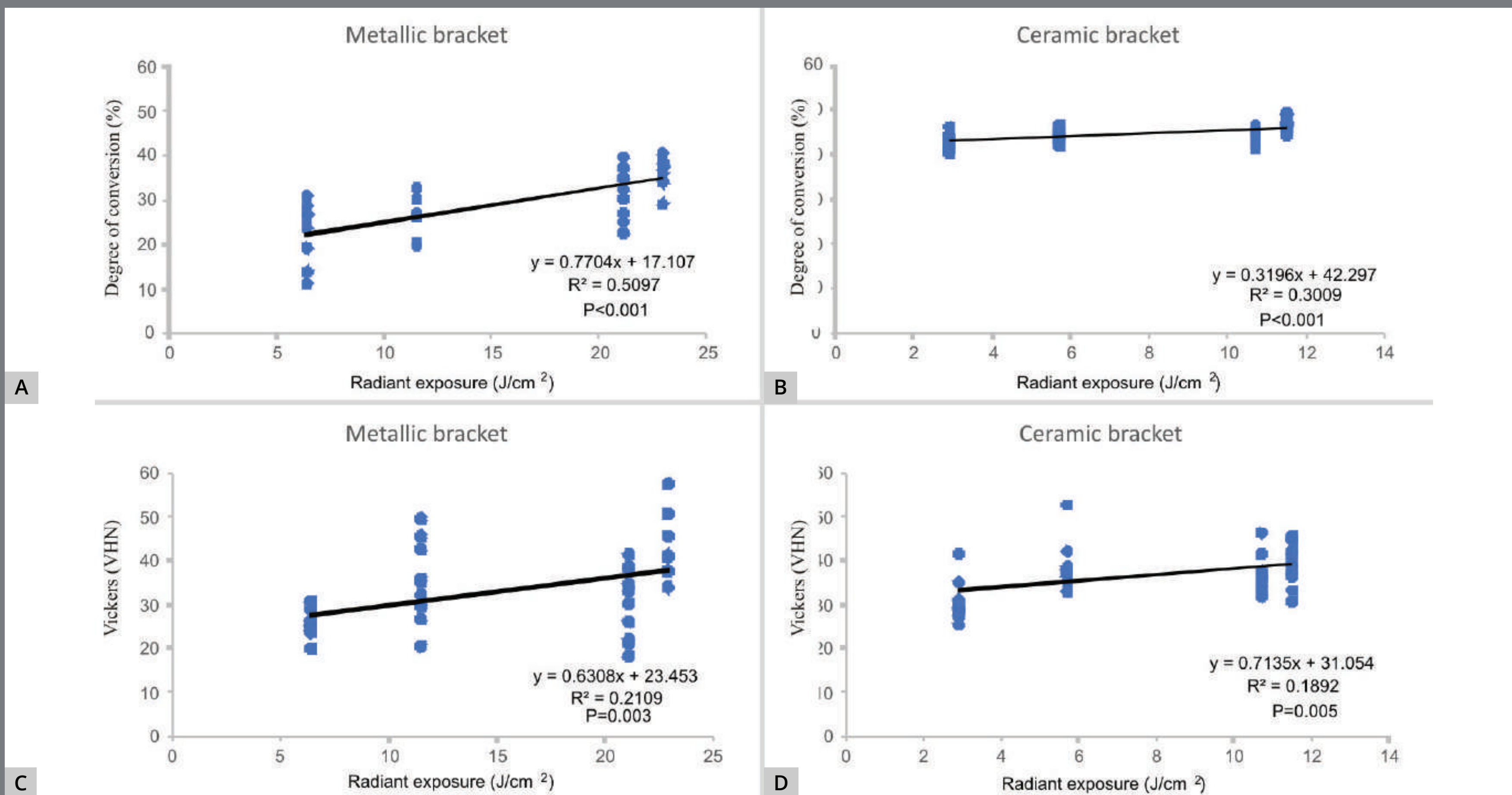

Figure 3: Regression analysis plot of DC and VHN values vs delivered RE by VALO through metallic (**A** and **C**, respectively) or ceramic brackets (**B** and **D**, respectively).

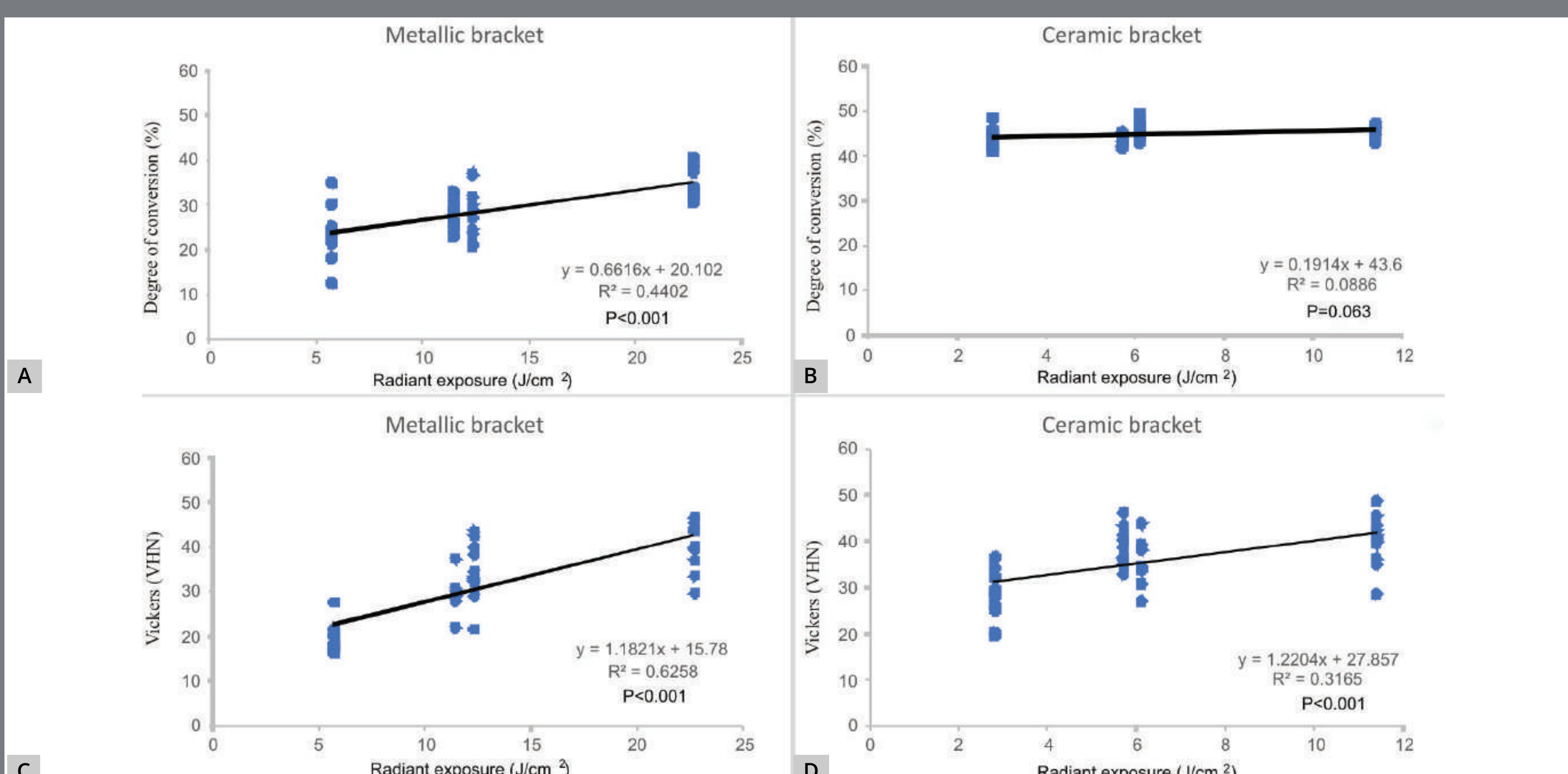

Figure 4: Regression analysis plot of DC and VHN values vs delivered RE by Bluephase20i through metallic (**A** and **C**, respectively) or ceramic brackets (**B** and **D**, respectively).

DISCUSSION

In the current study, the effects of varying RE on DC and VHN values of OC layer was influenced by the bracket type. More specifically, although no significant difference in Rp_{max} values was observed, most groups showed lower DC and VHN values when the delivered RE values corresponded to 1/2 and 1/4 of the MI, in comparison to the values observed in the control group when metallic brackets were used. Conversely, varying the RE values caused no significant difference in the DC and Rp_{max} values when ceramic brackets were used. Therefore, the first null hypothesis was partially accepted for the DC values and accepted for VHN values. These results are in agreement with previous findings,[20,21] and demonstrated that the use of metallic brackets require longer exposure periods due to the detrimental effects of light attenuation caused by the presence of those brackets interposed between the OC layer and LCU tip.

Although the reduction in RE values to 1/2 or 1/4 of that recommended in the MI caused lower VHN values in most experimental conditions, only a weak, linear, positive, significant relationship between RE values and either DC or VHN values was observed in most conditions. Indeed, no significant relationship was noted between RE values and the DC or VHN values when OC was exposed to light emitted from Bluephase20i through ceramic brackets (Figs 3 and 4). Therefore, the second null hypothesis stating that there is a direct relationship between RE values and either DC or VHN values was partly accepted. Such a weak relationship may be explained by the influence of the brackets interposed between OC and the LCU tip. When ceramic brackets are used, lower attenuation of the light emitted from LED LCUs is expected, in comparison to that when metallic brackets are used. As a consequence, even the lowest delivered RE values were capable of promoting close VHN values to or as high DC values as those obtained after following MI.

Differently from the results observed when ceramic brackets were used, DC and VHN values of OC layers under metallic brackets were apparently more severely affected by the reduction in the delivered RE values, as previously reported in other study.[20] This result may be attributed to the fact that curing light is entirely blocked by the presence of metallic bracket, so OC polymerization relied solely on the effects of light reaching the edge of metallic bracket. For this reason, higher RE values are required to ensure optimal polymerization and mechanical properties. As a consequence, apparently higher relationship between RE values and DC or VHN values was noted when metallic brackets were used, in comparison to that observed when ceramic brackets were used. Therefore, the second research hypothesis was accepted when metallic brackets were evaluated.

The lower attenuation in curing light caused by the presence of ceramic brackets, in comparison to that observed when metallic brackets are used, also helps explaining the higher Rp_{max} values and the consequent higher DC and VHN values observed when ceramic brackets are used. Therefore, the third hypothesis was accepted for DC, Rp_{max} and VHN values. This finding corroborates previous evidence that Rp_{max} values are related to radiant emittance values rather than to the exposure interval or RE values[6,22,23] and also helps explaining why the use of Plasma mode in VALO and Turbo mode in Bluephase20i resulted in higher Rp_{max} values than those observed in the other groups when ceramic brackets were used, despite the shorter exposure interval. As a consequence, the DC and VHN values after exposure to shorter exposure interval such as those applied when Plasma (VALO) or Turbo (Bluephase20i) were as high as those observed in the control groups (manufacturers' instructions) in most experimental conditions. In addition, the profile of polymerization kinetics in groups exposed to Plasma or Turbo modes at short exposure periods were similar to those observed in the control groups, corroborating the exposure reciprocity law previously observed in most photo-activated resin-based composites.[24,25]

The decrease in VHN values as a result of the reduced RE values delivered to OC layer were not closely related to that observed in the DC values. For instance, the delivery of 1/2 and 1/4 of the MI's recommended RE values though ceramic brackets decreased DC values in 4.9% and 8.5% in comparison to the values observed after exposure following MI when VALO was used, respectively. Conversely, the same exposure modes through ceramic brackets decreased VHN values in approximately 10.8% and 28.2% in comparison to the values after exposure according to MI. These results contradict the well documented correlation between monomer conversion and hardness of resin composites.[26] Such a lack of correlation between the DC and VHN values may be attributed to the difference between the regions of the OC surface where DC and VHN analyses were performed. More specifically, DC analysis was performed in the middle of the OC layer, while VHN analysis was performed at the corners of the OC layer. Because of the distribution of LED chips, the light emitted by most multi-peak, third generation LED CUs is not uniformly distributed regarding the irradiance and wavelength on the irradiated surface.[27] As a consequence, it is possible that lower radiant emittance values were delivered at the corners in comparison to those reaching the middle of the OC layer.

In this study, DC and VHN values were measured approximately 7 min after light exposure to LED CUs. Therefore, once polymerization of resin-based composites may continue for over 24 hours, further increase in DC values is expected. However, it should be emphasized that evaluating initial monomer conversion and hardness of orthodontic composites is crucial for the success of orthodontic treatment, as these products are subjected to tension soon after they are exposed to curing light. Thus, OCs should achieve optimal monomer conversion and mechanical properties within the first minutes after exposure to light emitted from LED CUs.[25] In addition, the current results were based on one commercially available photo-activated composite with camphorquinone as the main photoinitiator. As a consequence, the results should not be extrapolated to products with other photoinitiators. The current results cannot predict the actual influence of these exposure modes on bond strength and long-term consequences of bonding to enamel surface. Further investigation is required to address these issues.

CONCLUSION

Based on the current findings and within the limitations of the present study, it was possible to conclude that:

» Despite the slight decrease in VHN values, the decrease in RE values by the reduction in exposure interval did not jeopardize the DC or RPmax values when ceramic brackets are used, while DC and VHN values may be compromised by the reduction in the exposure interval when metallic brackets are used.

» A significant, but weak relationship was noted between RE values and DC and VHN values, regardless of bracket type.

» Exposure of OC to light through ceramic brackets results in higher DC, Rp_{max}, and VHN values than exposure through metallic brackets.

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REFERENCES

1. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res. 1955;34(6):849-53.
2. Newman GV. Epoxy adhesives for orthodontic attachments: progress report. Am J Orthod. 1965;51(12):901-12.
3. Grewal Bach GK, Torrealba Y, Lagravere MO. Orthodontic bonding to porcelain: a systematic review. Angle Orthod. 2014;84(3):555-60.
4. Reynolds IR. A review of direct orthodontic bonding. Br J Orthod. 2016;2(3):171-78.
5. Arrais CA, Giannini M, Rueggeberg FA. Kinetic analysis of monomer conversion in auto- and dual-polymerizing modes of commercial resin luting cements. J Prosthet Dent. 2009;101(2):128-36.
6. Arrais CA, Rueggeberg FA, Waller JL, Goes MF, Giannini M. Effect of curing mode on the polymerization characteristics of dual-cured resin cement systems. J Dent. 2008;36(6):418-26.
7. Goyal A, Hurkadle J, Magegowda S, Bhatia P. Use of light-curing units in orthodontics. J Investig Clin Dent. 2013;4(3):137-41.
8. Rueggeberg FA, Giannini M, Arrais CAG, Price RBT. Light curing in dentistry and clinical implications: a literature review. Braz Oral Res. 2017;31(suppl 1):e61.

9. Rueggeberg FA. State-of-the-art: dental photocuring--a review. Dent Mater. 2011;27(1):39-52.

10. Eliades T. Orthodontic materials research and applications: part 2. Current status and projected future developments in materials and biocompatibility. Am J Orthod Dentofacial Orthop. 2007;131(2):253-62.

11. Eliades T. Orthodontic materials research and applications: part 1. Current status and projected future developments in bonding and adhesives. Am J Orthod Dentofacial Orthop. 2006;130(4):445-51.

12. Peterson MR, Wong PH, Dickson SD, Coop CA. Allergic stomatitis from orthodontic adhesives. Mil Med. 2017;182(3):e1883-e5.

13. Kloukos D, Pandis N, Eliades T. Bisphenol-A and residual monomer leaching from orthodontic adhesive resins and polycarbonate brackets: a systematic review. Am J Orthod Dentofacial Orthop. 2013;143(Suppl. 4):S104-12.e1-2.

14. Rochester JR. Bisphenol A and human health: a review of the literature. Reprod Toxicol. 2013;42:132-55.

15. Rogers JA, Metz L, Yong VW. Review: endocrine disrupting chemicals and immune responses: a focus on bisphenol-A and its potential mechanisms. Mol Immunol. 2013;53(4):421-30.

16. Verma P. Curing efficiency of three light emitting diode units at different curing profiles. Indian J Dent Res. 2016;27(2):168-73.

17. Amato PAF, Martins RP, Cruz CAS, Capella MV, Martins LP. Time reduction of light curing: Influence on conversion degree and microhardness of orthodontic composites. Am J Orthod Dentofacial Orthop. 2014;146(1):40-6.

18. Rueggeberg FA, Craig RG. Correlation of parameters used to estimate monomer conversion in a light-cured composite. J Dent Res. 1988;67(6):932-7.

19. García-Contreras R, Scougall-Vilchis RJ, Acosta-Torres L, Arenas-Arrocena C, García-Garduño R, De La Fuente-Hernández J. Vickers microhardness comparison of 4 composite resins with different types of filler. J Oral Res. 2015;4(5):313-20.

20. Bolanos-Carmona V, Zein B, Menendez-Nunez M, Sanchez-Sanchez P, Ceballos-Garcia L, Gonzalez-Lopez S. Influence of the bracket on bonding and physical behavior of orthodontic resin cements. Dent Mater J. 2015;34(4):449-57.

21. Mavropoulos A, Cattani-Lorente M, Krejci I, Staudt CB. Kinetics of light-cure bracket bonding: power density vs exposure duration. Am J Orthod Dentofacial Orthop. 2008;134(4):543-7.

22. Cardoso KAORF, Zarpellon DC, Madrugada CFL, Rodrigues JA, Arrais CAG. Effects of radiant exposure values using second and third generation light curing units on the degree of conversion of a lucirin-based resin composite. J Appl Oral Sci. 2017;25(2):140-46.

23. Lee HM, Kim SC, Kang KH, Chang NY. Comparison of the bonding strengths of second- and third-generation light-emitting diode light-curing units. Korean J Orthod. 2016;46(6):364-71.

24. Halvorson RH, Erickson RL, Davidson CL. Energy dependent polymerization of resin-based composite. Dent Mater. 2002;18(6):463-9.

25. Emami N, Soderholm KJ. How light irradiance and curing time affect monomer conversion in light-cured resin composites. Eur J Oral Sci. 2003;111(6):536-42.

26. Ferracane JL. Correlation between hardness and degree of conversion during the setting reaction of unfilled dental restorative resins. Dent Mater. 1985;1(1):11-4.

27. Michaud PL, Price RB, Labrie D, Rueggeberg FA, Sullivan B. Localised irradiance distribution found in dental light curing units. J Dent. 2014;42(2):129-39.

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Stability of immediately loaded 3 mm long miniscrew implants: a feasibility study

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ABSTRACT

Introduction: Shorter miniscrew implants (MSIs) are needed to make orthodontics more effective and efficient.

Objective: To evaluate the stability, insertion torque, removal torque and pain associated with 3 mm long MSIs placed in humans by a novice clinician.

Methods: 82 MSIs were placed in the buccal maxillae of 26 adults. Pairs of adjacent implants were immediately loaded with 100g. Subjects were recalled after 1, 3, 5, and 8 weeks to verify stability and complete questionnaires pertaining to MSI-related pain and discomfort.

Results: The overall failure rate was 32.9%. The anterior and posterior MSIs failed 35.7% and 30.0% of the time, respectively. Excluding the 10 MSIs (12.2%) that were traumatically dislodged, the failure rates in the anterior and posterior sites were 30.1% and 15.2%, respectively; the overall primary failure rate was 23.6%. Failures were significantly ($p = 0.010$) greater (46.3% vs 19.5%) among the first 41 MSIs than the last 41 MSIs that were placed. Excluding the traumatically lost MSIs, the failures occurred on or before day 42. Subjects experienced very low pain (2.2% of maximum) and discomfort (5.5% of maximum) during the first week only.

Conclusions: Shorter 3 mm MSIs placed by a novice operator are highly likely to fail. However, failure rates can be substantially decreased over time with the placement of more MSIs. Pain and discomfort experienced after placing 3 mm MSIs is minimal and temporary.

Keywords: Miniscrew implants. Stability. Pain/discomfort. Experience.

RESUMO

Introdução: Mini-implantes (MIs) mais curtos são necessários para uma Ortodontia mais eficaz e eficiente.

Objetivo: Avaliar a estabilidade, o torque de inserção, torque de remoção e dor associada a MIs de 3 mm instalados em humanos por um ortodontista principiante.

Métodos: 82 MIs foram instalados na região vestibular da arcada superior de 26 adultos. Pares de mini-implantes adjacente receberam carga imediata de 100g. Após 1, 3, 5 e 8 semanas, os pacientes foram reavaliados para verificar a estabilidade e preencher um questionário sobre a dor e o desconforto relacionados aos MIs.

Resultados: A taxa geral de falhas foi de 32,9%, sendo de 35,7% para os MIs anteriores e 30% para os MIs posteriores. Excluindo os 10 MIs que foram perdidos por trauma (12,2%), a taxa de falha nas regiões anterior e posterior foi de 30,1% e 15,2%, respectivamente; e ocorreu no 42° dia ou antes. A taxa geral de falha primária foi de 23,6%. A taxa de falha foi significativamente maior (p=0,010) nos primeiros 41 MIs instalados do que nos 41 últimos (46,3% *vs.* 19,5%). Os pacientes relataram muito pouca dor (2,2% de dor máxima) e desconforto (5,5% de desconforto máximo), somente durante a primeira semana.

Conclusão: MIs de 3mm instalados por um novato são mais propensos a falhas. Porém, as taxas de falha podem diminuir substancialmente com a instalação de mais MIs no decorrer do tempo. A dor e o desconforto após a instalação desses dispositivos são mínimos e temporários.

Palavras-chave: Mini-implantes. Estabilidade. Dor/desconforto. Experiência.

INTRODUCTION

Miniscrew implants (MSIs) have become popular due to their easy placement and removal, effectiveness as anchorage devices, the multiplicity of intraoral placement options, their affordability, minimal invasiveness, and patient acceptance.[1,2] Systematic reviews have reported failure rates ranging between 13.5 and 20% when mobile and displaced MSIs were included.[3,4] Approximately 85% of practicing orthodontists reported MSI failures of 25% or less.[5] Although root injuries caused during MSI placement usually heal unremarkably, they have been shown to cause localized bone loss, ankylosis, and pulpal damage, leading to devitalization of the tooth.[6-8]

The risk of root contact during placement should be less for shorter 3 mm long MSIs than for traditional 6 to 8 mm long MSIs. Reports have shown that the soft tissue adjacent to the mucogingival junction is approximately 1-1.5 mm thick,[9,10] and that interradicular cortical bone is 0.8-3.1 mm thick in the mandible and 0.8-1.5 mm thick in the maxilla.[11,12] On that basis, no more than 1.5 mm of the screws' shanks would penetrate into medullary bone. That being the case, the risk of root contact in the buccal posterior region with 3 mm long MSIs should be minimal. For the same reasons, shorter screws should provide orthodontists with more MSI placement options, reduce the need for root separation, and could provide skeletal anchorage for dentofacial orthopedics in younger patients.

Experimental studies have shown that 3 mm long MSIs are stable in animal models. Excluding problematic MSIs (i.e. those whose tips broke off during insertion and those traumatically dislodged by animals chewing on their cages), an overall failure rate of 9.4% was reported for 3 mm screws placed in dog jaws and loaded with orthopedic level forces.[13] Failure rates under 10% have been reported in studies that placed 3 mm MSIs in the cranium of rabbits and loaded them with various orthodontic level forces.[14-17]

The purpose of this study was to assess the stability of immediately loaded 3 mm miniscrew implants placed in human subjects by a novice operator. No studies to date have examined the feasibility of using 3 mm long, 1.7 mm wide, MSIs in humans. Moreover, little is known about the number of MSIs that novice operators have to place in order to attain acceptable failure rates.

MATERIAL AND METHODS

SUBJECTS

After receiving approval by the Institutional Review Board, adults were recruited from the students and staff at Texas A&M University College of Dentistry. Exclusion criteria included: 1) pregnant females, 2) smokers, 3) subjects taking medications that could affect bone metabolism, 4) inadequate space between tooth roots and 5) buccal frenum in the placement site. Periapical radiographs were taken to ensure sufficient space between the MSIs and tooth roots (Fig 1).

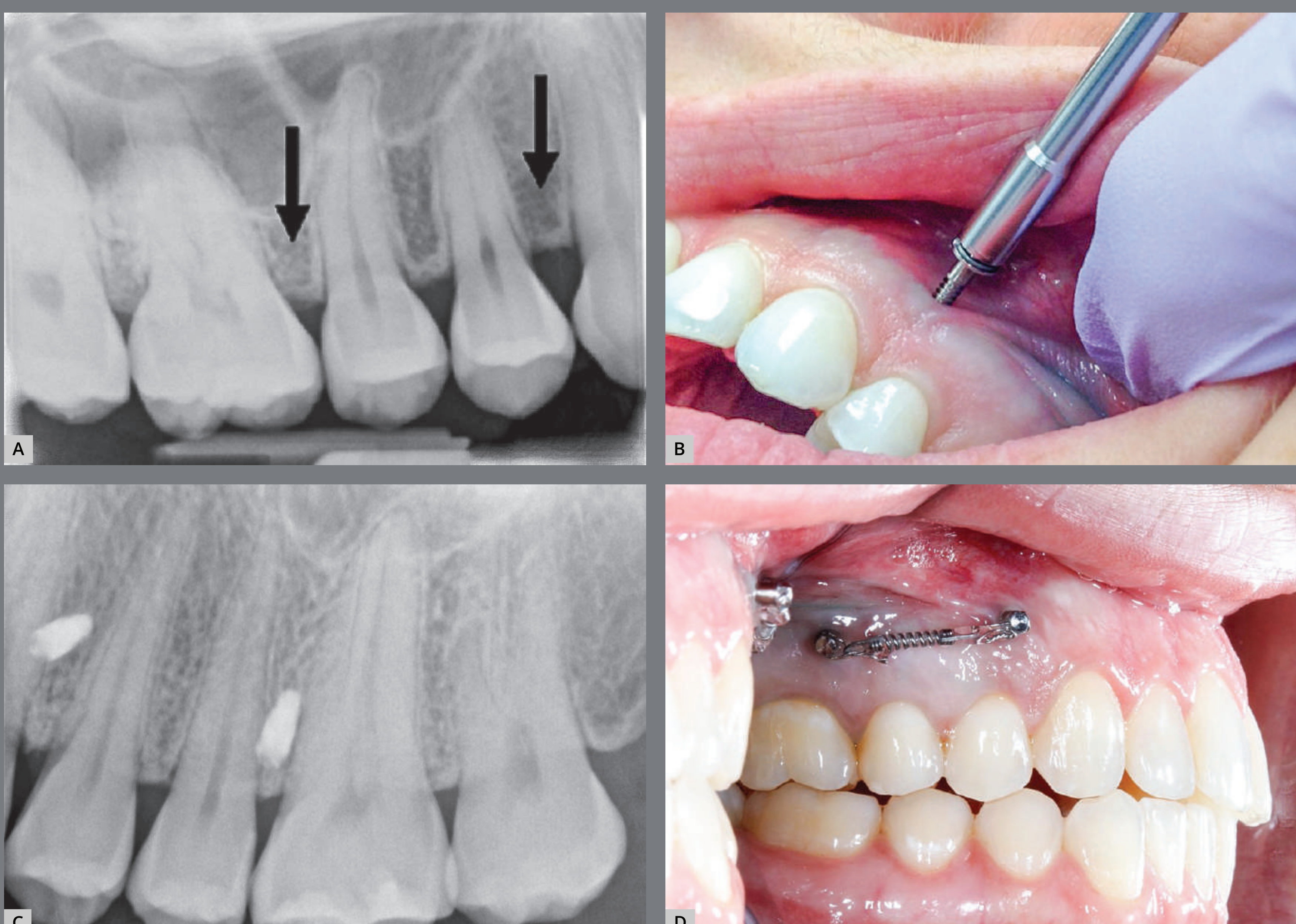

Figure 1: A) Periapical radiograph taken to visualize bone between the teeth (planned MSI sites indicated by black arrow**s)**, **B)** insertion of MSI, **C)** periapical radiograph taken after MSI placement, **D)** pair of MSIs after immediate loading with a force of 100 g.

A power analysis indicated that 80 screws were needed to establish a 15% difference in stability, assuming a power of 95% and an alpha of 0.05. A total of 82 MSIs were placed in 26 subjects (10 males, 16 females) with a mean age of 27.4 years. Each subject received $25 to compensate for their time and efforts. Seventeen subjects had MSIs placed on both sides (17 *x* 4 = 68), 6 had only one side that qualified (6 *x* 2 = 12), and 2 had only one (unloaded) MSI placed. The anterior MSI was placed between the maxillary canines and first premolars; the posterior MSI was placed between the second premolars and first molars. The protocol was approved by the Texas A&M University IRB. The purpose of the study and potential risks were explained, and an informed consent was obtained from each subject.

PLACEMENT PROTOCOL

All procedures were performed by one orthodontic resident using a standardized placement protocol. Subjects brushed their teeth and rinsed with Peridex chlorhexidine (3M ESPE, Irvine, CA) for 45 seconds. Topical anesthesia (20% lidocaine, 4% tetracaine, 2% phenylephrine) was applied at each MSI site for two minutes. Three subjects who requested additional anesthesia received anesthetic infiltration with 1/8 carpule of 2% lidocaine with 1:100,000 epinephrine. Gingival thickness was measured three times at the insertion site using a sharp explorer with an endodontic rubber stop.

Each 3 mm long, 1.7 mm wide MSI (Dentos, Seoul, Korea) was inserted perpendicularly into bone with a manual driver until the screw threads were no longer visible. Using a digital torque screwdriver (Imada, Northbrook, IL), each MSI was then rotated a quarter turn to measure insertion torque.

Periapical radiographs were taken after placement to ensure that there was space between the MSIs and the adjacent bone. Pairs of adjacent implants were immediately loaded with one nickel-titanium closed-coil spring (Ormco, Orange, CA) delivering a force of 100g. Triad gel (Dentsply, York, PA) was applied to prevent wire abrasion of the cheeks or gingiva. Following placement, subjects rinsed with Peridex for 45 seconds, and were instructed to rinse each night for one week. Intraoral photographs were taken and each subject was given written oral hygiene and miniscrew care instructions. Orthodontic wax was given to each subject to prevent cheek irritation. The distance between each pair of MSIs was measured with a caliper on the day of placement, as well as 1, 3, 5 and 8 weeks after placement. The distance was measured three times and averaged at each occasion.

MSIs were considered as failures if they exhibited any degree of mobility upon examination. If a screw failed, it was replaced if there was sufficient space intraorally to relocate the MSI apically. Screws were replaced whenever possible to maintain the

100g force on the other MSI that did not fail. Importantly, MSIs that were replaced were counted as failures. If both screws on one side failed, they were removed and not replaced. Failures were classified as either primary or incidental. Incidental failures occurred when the MSIs were traumatically dislodged by the subjects. After eight weeks, removal torque was recorded based on the first counterclockwise turn of each MSI using the digital torque screwdriver.

FOLLOW-UP

Subjects were recalled after 1, 3, 5, and 8 weeks. The eight week duration was chosen because the majority of MSI failures occur within one month after placement.[18-20] At each appointment, miniscrew stability was verified and the distance between implants was measured. Subjects also completed a questionnaire asking them to rate the worst pain that they ever experienced and the pain they were currently feeling, using a 10-cm Visual Analog Scale (VAS) anchored with “No pain” and “Worst pain ever”. Another question, anchored with “No discomfort” and “Worst discomfort ever”, asked how much discomfort the subjects were currently experiencing. The next two questions asked whether they took medications to relieve pain or discomfort associated with, and not associated with, the MSIs. The final question asked if the miniscrew implants caused any type of injury.

STATISTICAL ANALYSIS

SPSS Statistics version 22 (SPSS Inc, Chicago IL) was used for data analysis. Insertion torque, removal torque, and MSI distance data were analyzed using paired samples *t*-tests. Failures were evaluated using Chi-Square tests. Timing of failures was evaluated using non-parametric Mann-Whitney tests and differences between time points were compared using 2-tailed Wilcoxon Signed Rank tests. The survey responses were evaluated using Friedman tests. Statistical significance for all data was set at $p < 0.05$.

RESULTS

FAILURES

An implant was considered a failure if it exhibited any mobility upon examination (Table 1). The overall failure rate was 32.9% (27/82). Neither of the two unloaded MSIs failed. The failure rates of the anterior and posterior screws were 35.7% (15/42) and 30.0% (12/40), respectively. Ten of the 27 failures were incidental failures, where the MSIs were unintentionally but traumatically displaced by the subjects. The remaining failures were primary failures. The overall primary failure rate was 23.6% (17/72). The primary failure rates for the anterior and posterior screws were 30.1% (12/39) and 15.2% (5/33), respectively.

Table 1: Miniscrew failure rate.

	All failures (primary and incidental failures)	Primary failures (excluding incidental failures)
All MSIs	27/82 (32.9%)	17/72 (23.6%)
Anterior MSIs	15/42 (35.7%)	12/39 (30.1%)
Posterior MSIs	12/40 (30.0%)	5/33 (15.2%)

Table 2: Factors potentially associated with MSI failure.

Factor		Failed	Not failed	Sig.
Side	Right	14/46 (30.4%)	32/46 (69.6%)	0.587
	Left	13/36 (36.1%)	23/36 (63.9%)	
AP (all screws - 82 total)	Anterior	15/42 (35.7%)	27/42 (64.3%)	0.582
	Posterior	12/40 (30%)	28/40 (70%)	
AP (excluding incidental failures – 72 total)	Anterior	12/39 (30.8%)	27/39 (69.2%)	0.120
	Posterior	5/33 (15.2%)	28/33 (84.8%)	
	Late (last ½ placed)	5/38 (13.2%)	33/38 (86.8%)	

There was no significant difference in failure rate between MSIs placed on the right and left sides (Table 2) or between anterior and posterior screws. There were significantly more failures among the first 41 screws placed by the investigator than among the last 41, when all screws were considered and when incidentally displaced screws were excluded (Fig 2).

All primary failures occurred on or before day 42 (Fig 3); most failed between 15 and 26 days. Incidental failures, which began on day 19, displayed no clear pattern and continued throughout the eight-week study.

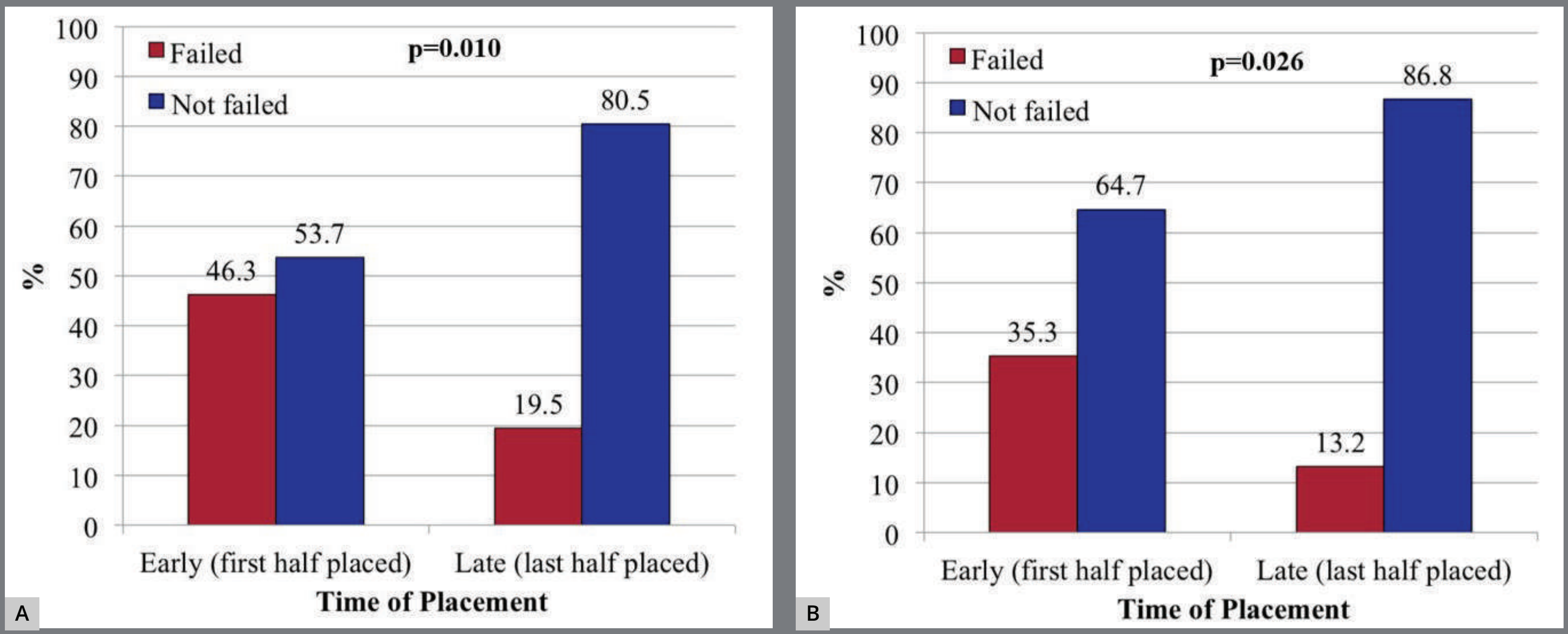

Figure 2: Percentages of MSI failures for those placed early (i.e., the first half of MSIs placed by investigator) and late (i.e., the last half), **A**) including all (82 total) and **B**) excluding incidental failures (72 total).

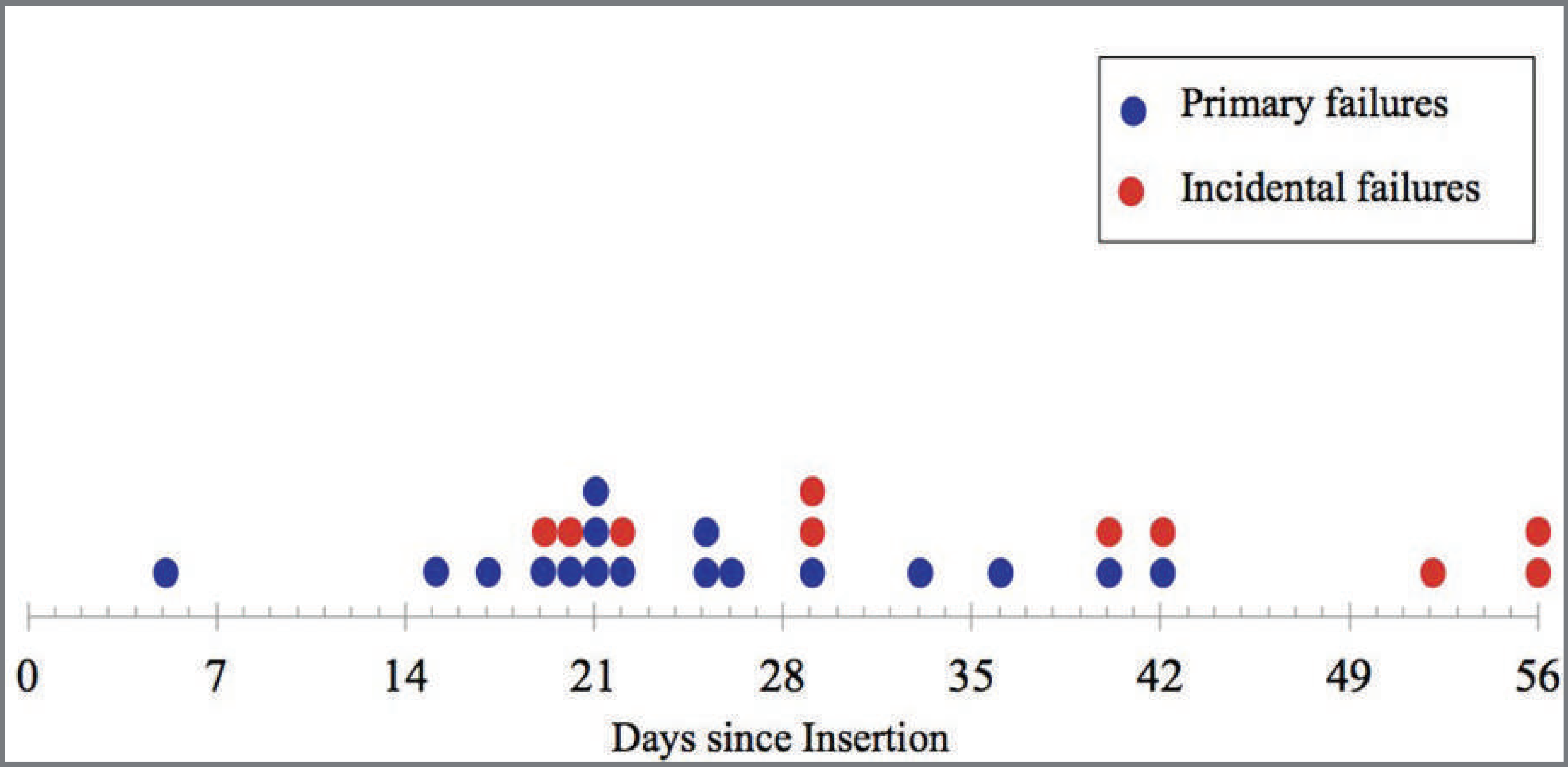

Figure 3: Days from the beginning of the study at which the primary and incidental failures occurred.

INSERTION AND REMOVAL TORQUE

Insertion torque was 7.8 ± 1.2 Ncm for the anterior screws and 7.4 ± 1.9 Ncm for the posterior screws, with no statistically significant anteroposterior difference (Table 3). There also was no statistically significant difference in removal torque between the anterior (1.7 ± 0.9 Ncm) and posterior (1.7 ± 0.7 Ncm) screws. Insertion torque was significantly ($p < 0.01$) greater than removal torque. While insertion and removal torque were higher for the MSIs that failed than for those that did not fail, none of the differences were statistically significant differences. However, insertion and removal torque were significantly less for the first 41 MSIs than the last 41 MSIs that were placed (Table 4).

Table 3: Mean MSI insertion and removal torque at 56 days.

		Insertion torque (Ncm)	Removal torque (Ncm)	Diff.
Anterior MSIs	Mean	7.75	1.71	**p < 0.001**
	SD	1.24	0.94	
Posterior MSIs	Mean	7.39	1.69	**p < 0.001**
	SD	1.92	0.70	
Diff.		p = 0.193	p = 0.686	

Bold terms indicate significance ($p < 0.05$).

Table 4: Differences in insertion and removal torque between the first and last 41 MSIs placed.

		First 41 MSIs		Last 41 MSIs		
Torque	MSIs	Mean	SD	Mean	SD	prob
Insertion (Ncm)	Anterior	7.29	1.02	8.23	1.12	**<0.001**
	Posterior	6.78	2.03	7.98	1.65	**0.006**
Removal (Ncm)	Anterior	1.47	1.11	1.80	0.86	0.32
	Posterior	1.42	0.70	1.96	0.59	**0.003**

GINGIVAL THICKNESS & TIPPING

Mean gingival thickness was 1.1 ± 0.3 mm at the anterior insertion sites, and 1.1 ± 0.1 mm at the posterior insertion sites (Fig. 4), a difference that was not statistically significant ($p = 0.745$). There were no statistically significant differences in gingival thickness between MSIs that failed and did not fail, or between the first 41 MSIs placed and the last MSIs placed.

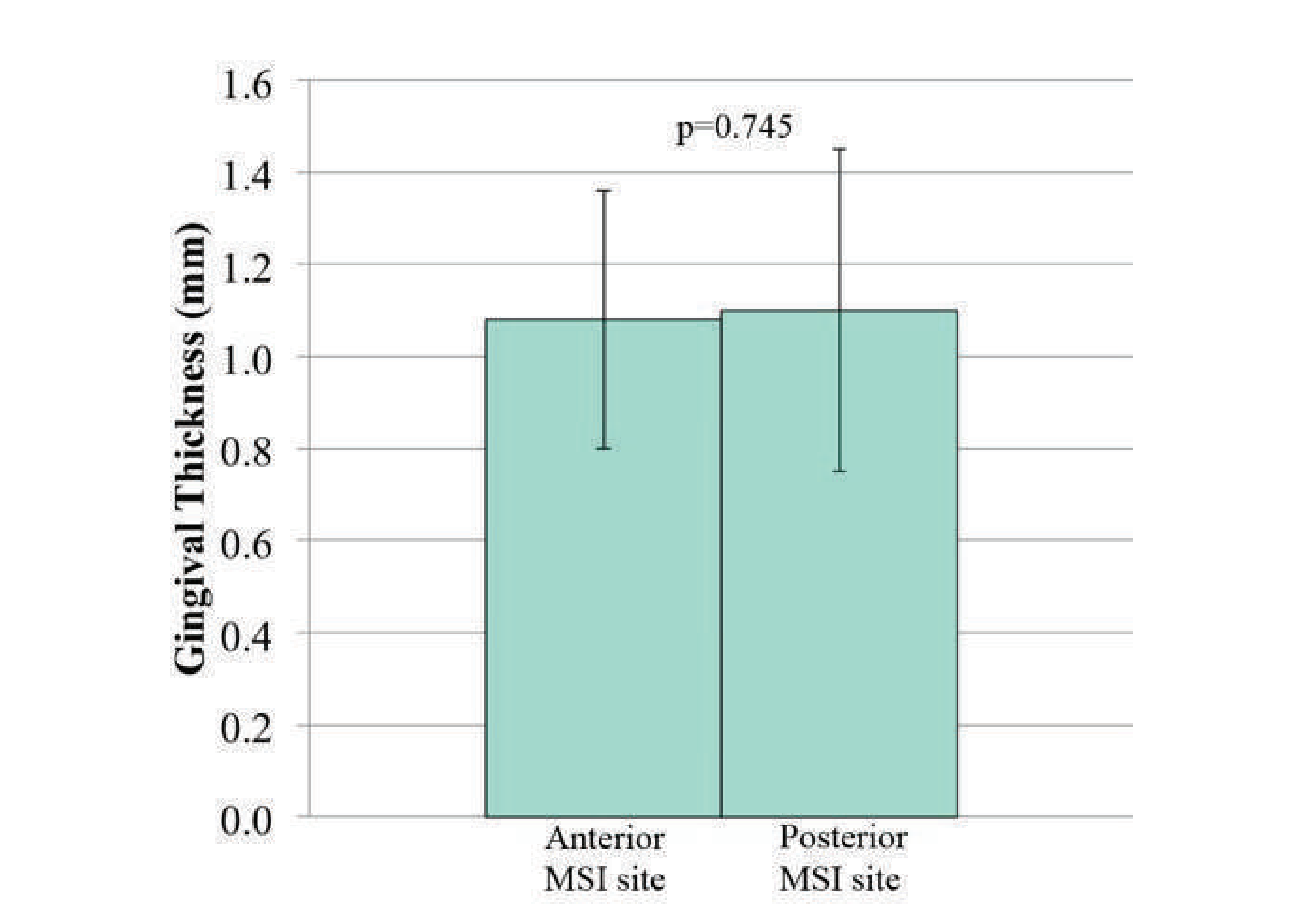

Figure 4: Gingival thickness measurements (mean ± SD) at the anterior and posterior MSI insertion sites.

The distances between pairs of adjacent MSIs decreased over time (Fig 5). Statistically significant decreases occurred between placement and week 1 ($p < 0.01$), as well as between weeks 1 and 3 ($p = 0.027$). Decreases thereafter were small and not statistically significant. While there were no statistically significant differences in the distances that the screws moved during the first three weeks between the first and last 41 MSIs placed, there were significantly greater movements of the MSIs that failed (Table 5).

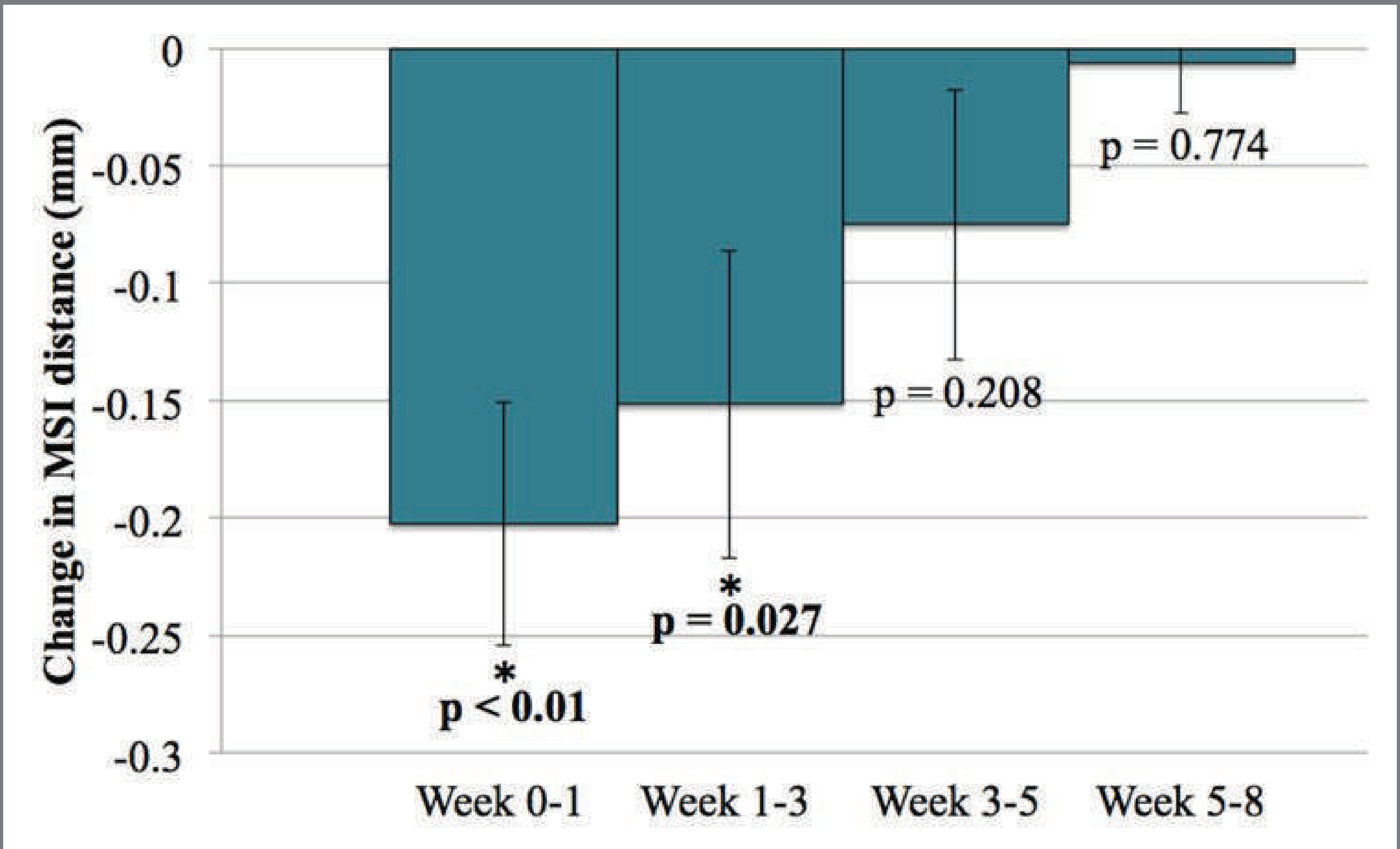

Figure 5: Mean change in distance between adjacent MSIs at each time interval (± standard error of the mean).

Table 5: Distances moved over the first 3 weeks of MSIs that failed and did not fail, with estimated for all, including and excluding incidental failures.

		Failed MSIs		Not Failed		
Torque	Weeks	Mean	SD	Mean	SD	prob
Including all screws	0-3	-0.64	0.48	-0.25	0.42	0.003
Excluding incidental failures	0-3	-0.69	0.40	-0.25	0.42	0.006

Table 6: Pain and discomfort [medians (Med) and interquartile ranges] associated with MSIs at follow-up evaluations, measured on a Visual Analog Scale.

	Week 1			Week 3			Week 5			Week 8		
%	25%	Med	75%	25%	Med	75%	25%	Med	75%	25%	Med	75%
Worst pain ever*	57.9	75.3	80.8	59.0	74.6	82.1	53.4	74.0	83.9	58.4	76.9	82.9
Current Pain	0.0	2.2	8.2	0.0	0.3	2.8	0.0	0.0	1.9	0.0	0.0	1.3
Current Discomfort	2.6	5.5	15.9	0.0	1.0	3.9	0.0	0.5	2.9	0.0	0.0	2.2

*Indicates the worst pain ever experienced by the subject prior to study participation.

QUESTIONNAIRES

Responses to the first question, regarding worst pain ever experienced, ranged from 74.0 to 76.9, with no statistically significant differences between the four time points (Table 6). Significant ($p < 0.01$) decreases in current pain and discomfort were reported between weeks 1 and 3, with no statistically significant changes thereafter.

The percentages of subjects taking medication to relieve MSI-associated pain or discomfort decreased significantly ($p < 0.01$), from 61.6% at week 1 to 4.2% at week 3. Approximately 2-29% of subjects reported taking analgesics for pain unrelated to the MSIs, with no statistically significant differences between time points. 46.2% of respondents indicated that the MSIs caused injuries during the first week, including cheek rubbing and mucosal ulceration (n = 8), gingival sloughing due to topical anesthetic (n = 2), and gingival irritation due to the coil spring (n = 2). One subject reported injury on week 5, due to a small cheek ulceration and another subject, who had a mobile screw, reported painful and swollen gingiva at week 8.

DISCUSSION

In the present study, 10 screws were traumatically dislodged by the subjects. These were the "incidental failures" that mostly (70%) occurred when subjects bit into large or tough foods. One anterior screw was traumatically displaced during tooth brushing. An informal survey of four clinical orthodontists, who together have over 42 years of experience using MSIs in their practices, indicated very few, if any, trauma-related failures. Fewer incidental failures might be expected among orthodontic patients because their diets are typically softer.[21] Also, the profile of orthodontic brackets and wires shields MSIs from food boluses during mastication and displaces the cheeks/lips of the gingiva. Since incidental trauma-related failures are expected to be less likely among orthodontic patients, both the total failures and the primary (i.e. non-traumatic) failures must be considered. Since 3 mm MSIs may pose a greater risk of choking than longer MSIs, it is important that they remain attached to appliances at all times.

The failure rate of 3 mm MSIs placed in the present study by a novice operator was substantially higher than rates reported for longer screws. The overall and primary failure rates were 32.9% and 23.6%, respectively. The most recent comprehensive systematic review of the literature indicates that approximately 13.5% of MSIs failed.[4] However, the review included studies with mobile screws, screws of various designs (several as long as 17 mm) placed throughout the oral cavity, and screws used for a variety of purposes.

While there are no comparative human studies using 3 mm MSIs, experimental animal studies have reported good success rates. The overall failure rate of loaded 3 mm MSIs placed in dog jaws was 9.4% after excluding MSIs whose tips broke off while being inserted and MSIs that were traumatically dislodged.[13] Studies that placed 3 mm MSIs in the cranium of rabbits and loaded them with various expansion forces reported failure rates of less than 10%.[14-17] The marked discrepancy between human and animal failure rates suggests that the stability of 3 mm MSIs depends on factors other than length.

Only two clinical studies evaluated shorter MSIs placed in the posterior buccal maxillary segment of humans. Suzuki et al.[22] reported a failure rate of 6.6%, with no differences in stability between immediately-loaded 5, 6, and 7 mm MSIs. In contrast, a 24.8% failure rate was reported for 5 mm MSIs that were loaded after 2-3 weeks.[23] The difference between these two studies further supports the notion that factors other than length determine the stability of shorter MSIs.

The insertion site could have been one factor that explains the higher than expected failure rates. Although not statistically significant, the primary failure rate for the anterior screws was twice as high (30.1 *vs* 15.2%) as the rate for MSIs placed between the second premolar and first molar. The anterior screws were often placed in non-keratinized movable mucosa, which is a known risk factor for miniscrew failure.[24]

Clinical experience was an important determinant of MSI success. The first 41 screws placed were much more likely to fail than those placed during the second half of the study (46.3% *vs* 19.5% failure). The primary failure rates during the last half was only 13.2%, which is similar to or less than failure rates reported for longer screws.[3-5] Experience explains why others have reported lower MSI failure rates,[25,26] and why failure rates are less among professors than postgraduate students (1.9% *vs* 29.2%).[27] A novice operator's failure rates with 5 mm MSIs decreased from 25% during the first 18 months to 8.8% during the next 18 months.[28] The significantly lower insertion and removal torque found in the present study for the first 41 MSIs placed suggests that the bone was damaged to a greater extent and required more healing. This could have been due to greater speed of insertion or less stability (e.g. wobble) during the insertion process. The greater movements observed between MSIs that failed also indicates less primary stability.

Failures of 3 mm MSIs mostly occurred two to four weeks after insertion. This confirms retrospective studies showing most MSI failures occurring during the first month after placement.[18-20] Dog studies reveal that MSI stability decreases during the first three weeks, and then increases.[29,30] Stability decreases because damaged bone must be removed during the initial stages of healing; stability increases after 3-4 weeks as bone deposition and remodeling surpass the resorption of the old bone.

Insertion torque indicated that the primary stability of 3 mm MSIs is similar to the primary stability of longer screws.[31,32] Higher insertion torques have been reported for longer self-drilling MSIs.[24]

Insertion torque in the present study was within 5-10 Ncm recommended for MSIs.[21] Shorter and longer screws likely exhibit comparable insertion torque because primary stability depends mostly on the cortical thickness and density.[33]

Removal torque of the 3 mm MSIs demonstrated reduced secondary stability. The average removal torque for the 3 mm MSIs was 1.7 Ncm, which is lower than removal torques previously reported for longer screws.[18,32] This was primarily due to the short eight week healing time in the present study. Also, shorter screws have less surface area than longer screws and less bone-to-implant contact for osseointegration. Bone forms along the entire surface of MSIs during the healing phase.[34,35]

In the present study, the distances between pairs of implants decreased significantly during the first three weeks. Clinically, the change was minimal, with an average total decrease of only 0.5 mm. Longer 17 mm MSIs have been reported to tip after placement,[36,37] with the amount being related to the amount of force applied.[13] The majority of MSI tipping probably occurs during the first few weeks, before newly remodeled bone achieves intimate contact with the MSI threads.[30]

Pain and discomfort experienced after MSI insertion was minimal. There was only slight pain and discomfort after the first week, and little or none thereafter. While patients expect MSIs to be moderately or very painful before placement, they report no pain or mild pain after treatment.[38] Longer (6-12 mm) MSIs produce less than half as much pain as traditional orthodontic appliances.[39,40] Pain could be even further reduced with the shorter 3 mm MSIs because they are less likely to contact the periodontal ligament, assuming that less than 1.5 mm of the screw's shank is expected to penetrate the medullary bone. Pain for the subjects in the present study was due to soft tissue injuries caused by MSI placement, including cheek rubbing, ulceration, gingival sloughing from topical anesthetic, and gingival irritation from the coil springs.

CONCLUSIONS

3 mm MSIs placed in humans by a novice operator are likely to fail approximately 1/3 of the time.

With the placement of more MSIs over time, failure rates decrease to approximately 20%.

Failures of 3 mm MSIs occur mostly between 2 and 4 weeks after insertion.

3 mm MSIs have acceptable levels of insertion torque, but low removal torque after eight weeks of healing.

3 mm MSIs tip during the first three weeks after insertion, with greater movements of the MSIs that fail.

Pain and discomfort experienced after 3 mm MSI placement is minimal and temporary.

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Patients displayed in this article previously approved the use of their facial and intraoral photographs.
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REFERENCES

1. Favero L, Brollo P, Bressan E. Orthodontic anchorage with specific fixtures: related study analysis. Am J Orthod Dentofacial Orthop. 2002;122(1):84-94.
2. Kau CH, English JD, Muller-Delgardo MG, Hamid H, Ellis RK, Winklemann S. Retrospective cone-beam computed tomography evaluation of temporary anchorage devices. Am J Orthod Dentofacial Orthop. 2010;137(2):166.e1-5.
3. Reynders R, Ronchi L, Bipat S. Mini-implants in orthodontics: a systematic review of the literature. Am J Orthod Dentofacial Orthop. 2009;135(5):564.e1-19.
4. Papageorgiou SN, Zogakis IP, Papadopoulos MA. Failure rates and associated risk factors of orthodontic miniscrew implants: a meta-analysis. Am J Orthod Dentofacial Orthop. 2012;142(5):577-595.e7.
5. Buschang PH, Carrillo R, Ozenbaugh B, Rossouw PE. 2008 survey of AAO members on miniscrew usage. J Clin Orthod. 2008;42(9):513-518.
6. Chen YH, Chang HH, Chen YJ, Lee D, Chiang HH, Yao CC. Root contact during insertion of miniscrews for orthodontic anchorage increases the failure rate: an animal study. Clin Oral Implants Res. 2008;19(1):99-106.

7. Brisceno CE, Rossouw PE, Carrillo R, Spears R, Buschang PH. Healing of the roots and surrounding structures after intentional damage with miniscrew implants. Am J Orthod Dentofacial Orthop. 2009;135(3):292-301.

8. Hembree M, Buschang PH, Carrillo R, Spears R, Rossouw PE. Effects of intentional damage of the roots and surrounding structures with miniscrew implants. Am J Orthod Dentofacial Orthop. 2009;135(3):280.e1-9.

9. Goaslind GD, Robertson PB, Mahan CJ, Morrison WW, Olson JV. Thickness of facial gingiva. J Periodontol. 1977;48(12):768-771.

10. Cha BK, Lee YH, Lee NK, Choi DS, Baek SH. Soft tissue thickness for placement of an orthodontic miniscrew using an ultrasonic device. Angle Orthod. 2008;78(3):403-8.

11. Farnsworth D, Rossouw PE, Ceen RF, Buschang PH. Cortical bone thickness at common miniscrew implant placement sites. Am J Orthod Dentofacial Orthop. 2011;139(4):495-503.

12. Cassetta M, Sofan AA, Altieri F, Barbato E. Evaluation of alveolar cortical bone thickness and density for orthodontic mini-implant placement. J Clin Exp Dent. 2013;5(5):e245-52.

13. Mortensen MG, Buschang PH, Oliver DR, Kyung HM, Behrents RG. Stability of immediately loaded 3- and 6-mm miniscrew implants in beagle dogs--a pilot study. Am J Orthod Dentofacial Orthop. 2009;136(2):251-9.

14. Liu SS, Opperman LA, Kyung HM, Buschang PH. Is there an optimal force level for sutural expansion? Am J Orthod Dentofacial Orthop. 2011;139(4):446-55.

15. Liu SS, Kyung HM, Buschang PH. Continuous forces are more effective than intermittent forces in expanding sutures. Eur J Orthod. 2010;32:371-80.

16. Liu SS, Opperman LA, Buschang PH. Effects of recombinant human bone morphogenetic protein-2 on midsagittal sutural bone formation during expansion. Am J Orthod Dentofacial Orthop. 2009;136(6):768.e1-e8.

17. Truong P, Campbell PM, Kontogiorgos E, Taylor RW, Buschang PH. Effect of longitudinally flutes on miniscrew implant stability and 3-dimensional bone formation. Am J Orthod Dentofacial Orthop. 2016;150(6):950-7.

18. Migliorati M, Drago S, Gallo F, Amorfini L, Dalessandri D, Benedicenti S, et al. Immediate versus delayed loading: comparison of primary stability loss after miniscrew placement in orthodontic patients-a single-centre blinded randomized clinical trial. Eur J Orthod. 2016;38(6):652-9.

19. Aboul-Ela SM, El-Beialy AR, El-Sayed KM, Selim EM, El-Mangoury NH, Mostafa YA. Miniscrew implant-supported maxillary canine retraction with and without corticotomy-facilitated orthodontics. Am J Orthod Dentofacial Orthop. 2011;139(2):252-9.

20. Upadhyay M, Yadav S, Nagaraj K, Patil S. Treatment effects of mini-implants for en-masse retraction of anterior teeth in bialveolar dental protrusion patients: a randomized controlled trial. Am J Orthod Dentofacial Orthop. 2008;134(1):18-29.e1.

21. Wiedel AP, Bondemark L. A randomized controlled trial of self-perceived pain, discomfort, and impairment of jaw function in children undergoing orthodontic treatment with fixed or removable appliances. Angle Orthod. 2015; 86(2):324-30.

22. Suzuki M, Deguchi T, Watanabe H, Seiryu M, Iikubo M, Sasano T, et al. Evaluation of optimal length and insertion torque for miniscrews. Am J Orthod Dentofacial Orthop. 2013;144(2):251-9.

23. Baek SH, Kim BM, Kyung SH, Lim JK, Kim YH. Success rate and risk factors associated with mini-implants reinstalled in the maxilla. Angle Orthod. 2008;78(5):895-901.

24. Topouzelis N, Tsaousoglou P. Clinical factors correlated with the success rate of miniscrews in orthodontic treatment. Int J Oral Sci. 2012;4(1):38-44.

25. Fritz U, Ehmer A, Diedrich P. Clinical suitability of titanium microscrews for orthodontic anchorage-preliminary experiences. J Orofac Orthop. 2004;65(5):410-8.

26. Garfinkle JS, Cunningham Jr. LL, Beeman CS, Kluemper GT, Hicks EP, Kim MO. Evaluation of orthodontic mini-implant anchorage in premolar extraction therapy in adolescents. Am J Orthod Dentofacial Orthop. 2008;133(5):642-53.

27. Oh YH, Park HS, Kwon TG. Treatment effects of microimplant-aided sliding mechanics on distal retraction of posterior teeth. Am J Orthod Dentofacial Orthop. 2011;139(4):470-81.

28. Kim YH, Yang SM, Kim S, Lee JY, Kim KE, Gianelly AA, et al. Midpalatal miniscrews for orthodontic anchorage: factors affecting clinical success. Am J Orthod Dentofacial Orthop. 2010;137(1):66-72.

29. Ure DS, Oliver DR, Kim KB, Melo AC, Buschang PH. Stability changes of miniscrew implants over time. Angle Orthod. 2011;81(6):994-1000.

30. Cuairan C, Campbell PM, Kontogiorgos E, Taylor RW, Melo AC, Buschang PH. Local application of zoledronate enhances miniscrew implant stability in dogs. Am J Orthod Dentofacial Orthop. 2014;145(6):737-49.

31. Motoyoshi M, Hirabayashi M, Uemura M, Shimizu N. Recommended placement torque when tightening an orthodontic mini-implant. Clin Oral Implants Res. 2006;17(1):109-14.

32. Suzuki EY, Suzuki B. Placement and removal torque values of orthodontic miniscrew implants. Am J Orthod Dentofacial Orthop. 2011;139(5):669-78.

33. Meursinge Reynders RA, Ronchi L, Ladu L, Van Etten-Jamaludin F, Bipat S. Insertion torque and success of orthodontic mini-implants: a systematic review. Am J Orthod Dentofacial Orthop, 2012;142(5):596-614.e5.

34. Ikeda H, Rossouw PE, Campbell PM, Kontogiorgos E, Buschang PH. Three-dimensional analysis of peri-bone-implant contact of rough-surface miniscrew implants. Am J Orthod Dentofacial Orthop. 2011;139(2):e153-e63.

35. Massey CC, Kontogiorgos E, Taylor R, Opperman L, Dechow P, Buschang PH. Effect of force on alveolar bone surrounding miniscrew implants: a 3-dimensional microcomputed tomography study. Am J Orthod Dentofacial Orthop. 2012;142(1):32-44.

36. Liou EJ, Pai BC, Lin JC. Do miniscrews remain stationary under orthodontic forces? Am J Orthod Dentofacial Orthop. 2004;126(1):42-47.

37. Garg KK, Gupta M. Assessment of stability of orthodontic mini-implants under orthodontic loading: a computed tomography study. Indian J Dent Res. 2015;26(3):237-43.

38. Buschang PH, Carrillo R, Rossouw PE. Orthopedic correction of growing hyperdivergent, retrognathic patients with miniscrew implants. J Oral Maxillofac Surg. 2011;69(3):754-62.

39. Kuroda S, Sugawara Y, Deguchi T, Kyung HM, Takano-Yamamoto T. Clinical use of miniscrew implants as orthodontic anchorage: success rates and postoperative discomfort. Am J Orthod Dentofacial Orthop. 2007;131(1):9-15.

40. Scheurer PA, Firestone AR, Burgin WB. Perception of pain as a result of orthodontic treatment with fixed appliances. Eur J Orthod. 1996;18(4):349-57.

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ORIGINAL ARTICLE

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Evaluation of the palatal bone in different facial patterns for orthodontic mini-implants insertion: A cone-beam computed tomography study

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ABSTRACT

Objective: Evaluate the height, thickness and cortical density of the palatal bone of adults with different vertical facial patterns using Cone-Beam Computed Tomography (CBCT).

Methods: This study analyzed 75 CBCTs of patients between 18 and 35 years old (45 men and 30 women). The CBCTs were classified into three groups based on their facial pattern: normodivergent, hypodivergent and hyperdivergent as determined from lateral cephalograms synthesized from the CBCTs. The height, cortical thickness and cortical density of the palatal bone were measured at 4, 8, 12, 16 and 20mm posterior to the incisive foramen, and at 3, 6 and 9mm lateral to the midpalatal suture. ANOVA with Tukey *post-hoc* tests were used for analysis of the data, at significance level of $p < 0.05$.

Results: The hypodivergent pattern had a significant difference and the greatest height and cortical thickness of the palatal bone, followed by the hyperdivergent and the normodivergent patterns. No significant differences were found in minimum and maximum values of cortical density.

Conclusion: The palatal bone is a favorable anatomical area to install different orthodontic temporary anchorage devices (TADs), where individuals with the hypodivergent vertical facial pattern have a higher height and cortical thickness of the palatal bone, followed by the hyperdivergent pattern and finally the normodivergent pattern. No significant differences in the cortical density of the palatal bone in the three facial patterns were found.

Keywords: Cone-beam computed tomography. Orthodontic anchorage procedure. Palate.

RESUMO

Objetivo: Avaliar a altura, a espessura e a densidade cortical do osso palatino em adultos com diferentes padrões faciais verticais, utilizando a tomografia computadorizada de feixe cônico (TCFC).

Métodos: O presente estudo analisou 75 TCFCs de pacientes com idades entre 18 e 35 anos (45 homens e 30 mulheres). As TCFCs foram classificadas em três grupos, de acordo com o padrão facial: normodivergente, hipodivergente ou hiperdivergente, conforme determinado nas radiografias cefalométricas laterais reconstruídas das TCFCs. A altura, espessura e densidade cortical do osso palatino foram aferidas a 4, 8, 12, 16 e 20 mm para posterior do forame incisivo e a 3, 6 e 9 mm lateralmente à sutura transpalatina. Os testes ANOVA e *post-hoc* de Tukey foram utilizados para análise dos dados, com nível de significância de $p < 0,05$.

Resultados: O padrão hipodivergente apresentou uma diferença significativa e a maior altura e espessura cortical do osso palatino, seguido pelos padrões hiperdivergente e normodivergente. Nenhuma diferença estatisticamente significativa foi encontrada nos valores mínimos e máximos da densidade cortical.

Conclusão: O osso palatino é uma área anatomicamente favorável para instalar diferentes dispositivos de ancoragem temporária (DATs). Indivíduos com padrão facial vertical hipodivergente apresentam maior altura e espessura cortical do osso palatino, seguido do padrão hiperdivergente e, finalmente, do padrão normodivergente. Não foi encontrada qualquer diferença significativa, entre os três padrões faciais, na densidade cortical do osso palatino.

Palavras-chave: Tomografia computadorizada feixe cônico. Procedimento de ancoragem ortodôntica. Palato.

INTRODUCTION

During orthodontic treatment, teeth are exposed to forces and moments generated by the appliances used. The applied forces generate reciprocal forces of the same magnitude in the opposite direction. Thus, one of the most difficult clinical challenges is to minimize these reciprocal forces. Successful treatment generally depends on meticulous planning of the anchorage.[1] A reliable method is to use temporary anchorage devices (TADs).

The palatal region is very important for the installation of TADs as an aid in the orthodontic treatment, showing a high clinical versatility, with more precise and predictable tooth movement regardless of patient cooperation.[2,3]

One factor determining the success of TADs placement is the quantity of the surrounding bone.[4] The insertion on the palate depends on the structural characteristics of the palatine bone, such as height, cortical thickness and cortical density. It has been reported that a suitable bone thickness of the palate should be greater than 4 mm.[5] Bone characteristics can be evaluated through the cone-beam computed tomography (CBCT), which provides highly accurate and detailed information.[6,7]

The skeletal morphology in the craniofacial region is primarily controlled by genetic factors. However, the functional demands can have a significant effect on the growth and craniofacial development.

Each of the facial patterns in the vertical dimension (hyperdivergent, normodivergent and hypodivergent) present differences in the muscle load during function, due to skeletal compensation. This muscle load can alter the height and thickness of the cortical bone and the density of the palatal bone, not only in muscle attachment sites but also in other skeletal sections.[8] It could be said that there is a significant relationship between the facial type and the morphological characteristics of the jaws.[9-11] Sadek et al.[10] reported that patients with a hyperdivergent pattern have a narrow alveolus, compared to the normal and hypodivergent patients.

The aim of this study was to determine the height, thickness and cortical density characteristics of the palatal bone in the different vertical facial patterns using CBCTs. This information would give background or guidelines in terms of possible TAD placement sites in the palatal bone dependent on the patient growth pattern.

MATERIAL AND METHODS

This study analyzed 75 CBCTs (25 normodivergent, 25 hypodivergent and 25 hyperdivergent), from patients between 18 and 35 years old, with permanent dentition and in maximum intercuspation (45 men and 30 women). The sample size formula was applied to estimate an average: $n= 2(Z_{\alpha}+Z_{\beta})^{2*}S^2/d^2$. Patients with facial asymmetries, hyperplasia and obvious craniofacial syndromes, cleft lip and palate, systemic diseases, and presence of impacted teeth in the palatal region were excluded. Subjects were classified into one of three groups, based on their vertical facial pattern and with no sagittal malocclusion, as determined from lateral cephalograms synthesized from the CBCTs. These facial patterns were determined by the angle formed using the following cephalometric measurements: 1) Mandibular plane — the angle between the anterior cranial base (sella to nasion) and Mandibular plane (gonion to menton) — patients between 29 to 36 degrees were classified as normodivergent; patients with more than 36 degrees, as hyperdivergent; and less than 29 degrees, as hypodivergent;[12] 2) Face height index — the ratio of posterior face height to anterior face height, using the measurements of distance from sella (S) to gonion (Go) divided by the distance of nasion (N) to menton (Me) — ratios of < 61%, 61% to 69%, and > 69% indicated hyperdivergent, normodivergent and hypodivergent patterns, respectively[13] (Fig 1 and Table 1).

Subjects had to fit into a single facial pattern category for both measurements, in order to be included in the study.

The normodivergent pattern group consisted of 16 men and 9 women with an average age of 25.88 years; the hyperdivergent pattern group, by 14 men and 11 women, with an average age of 24.04 years; and hypodivergent pattern group, by 15 men and 10 women, with an average age of 25.84 years.

The study protocol was approved by the Ethnical Committee of Peruvian Cayetano Heredia University (493-23-15).

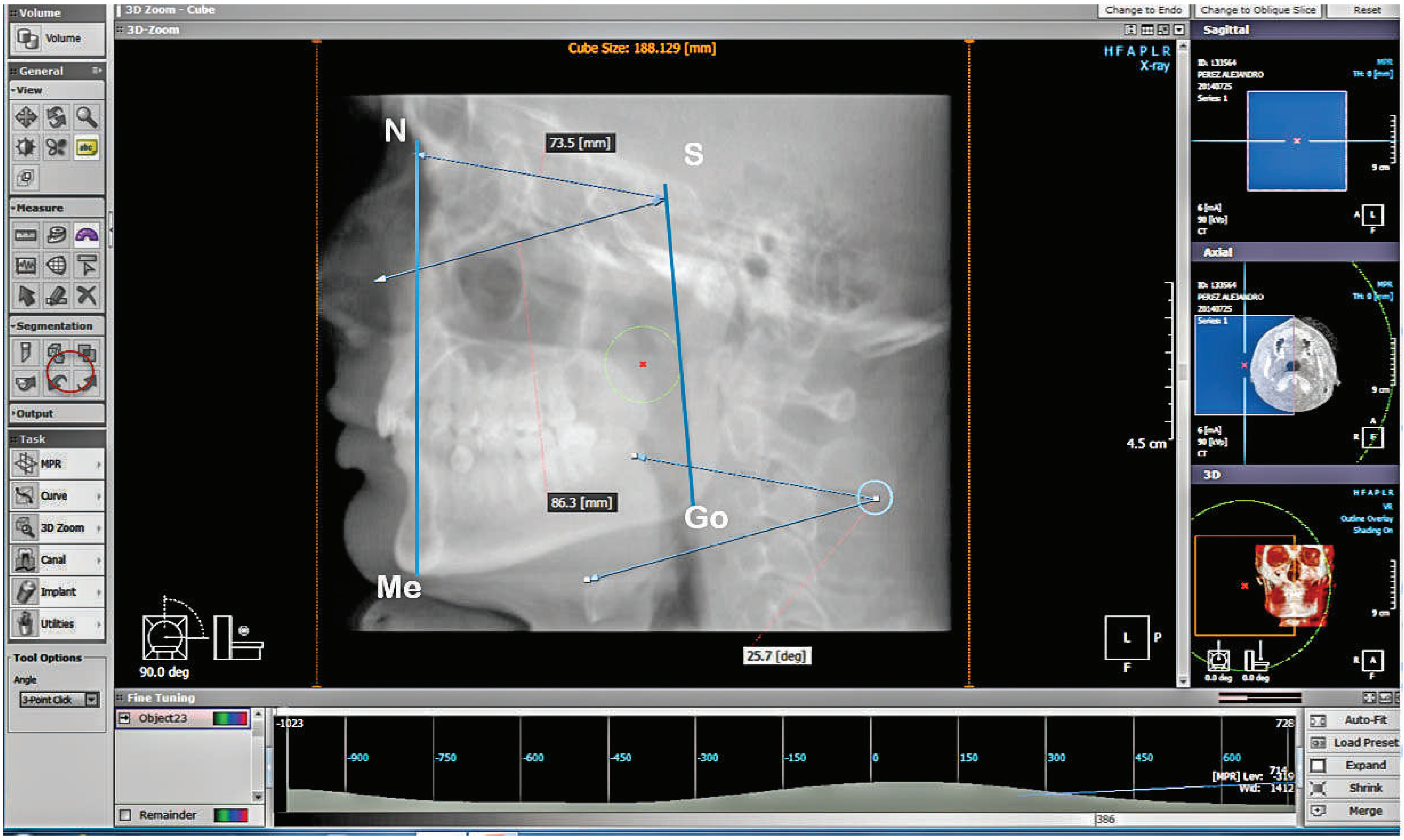

Figure 1: Measurements of facial patterns: 1) Anterior cranial base (sella [S] to nasion [N]) and mandibular plane (gonion to menton), 2) Face height index, the ratio of posterior face height to anterior face height using the measurements of distance from sella (S) to gonion (Go) divided by the distance of nasion (N) to menton (Me).

Table 1: Average ($\bar{X}$) and standard deviation (SD) of the distribution, by vertical facial patterns.

DIMENSIONS	VERTICAL FACIAL PATTERN			
	Normodivergent	Hyperdivergent	Hypodivergent	
	$\bar{X}$ (SD)	$\bar{X}$ (SD)	$\bar{X}$ (SD)	Total
Patients (n)	25	25	25	75
SN/GoMe (degrees)	33.26 (3.12)	42.42 (2.94)	20.71 (3.58)	
PFH/AFH (%)	66.90 (2.13)	55.87 (2.79)	82.35 (4.56)	

All CBCTs were obtained from the Picasso Master CBCT (Vatech, Hwaseong, Korea), from the archives of patients previously treated for diagnostic reasons at the Section of Orthodontics, during the period of 2010 to 2016. The following settings were used: 120 kVp, 5 mA, scan time of 24 seconds, large field of view (20 cm x 19 cm), with a voxel size of 0.3mm. The three-dimensional (3D) images werere constructed using the Real Scan, version 2.0 software (Seoul, Korea). An orthodontist trained in using the software analyzed all CBCTs.

All images were oriented in the standardized position before performing the measurements. In the axial view, the coordinate axis was placed at the midpoint between the infraorbital hole and the external ear canal, increasing the thickness of the image to 30mm so that both structures could be seen in the sagittal view. In the sagittal view, the tomographic volume was positioned in such a way that the Frankfort plane (Porion-Orbital) was parallel to the lower edge of the window. After locating the incisive foramen and posterior nasal spine (PNS) in the axial view, a reference line was constructed across the midpalatal suture. In the sagittal view, a midsagittal reference line was then projected through the distal margin of the incisive foramen and PNS.

All subsequent measurements were made perpendicular to this reference line[9-15] (Fig 2).

Measurements were taken at 4, 8, 12, 16 and 20mm posterior to the incisive foramen and were designated as P4, P8, P12, P16 and P20, respectively. Measurements taken at 3, 6 and 9mm lateral to midpalatal suture were designated as D3, D6 and D9, respectively. A total of 15 measurements were performed for each patient (Fig 3). Several studies used these measurements to evaluate the palatal bone before the installation of TADs.[9,11,12]

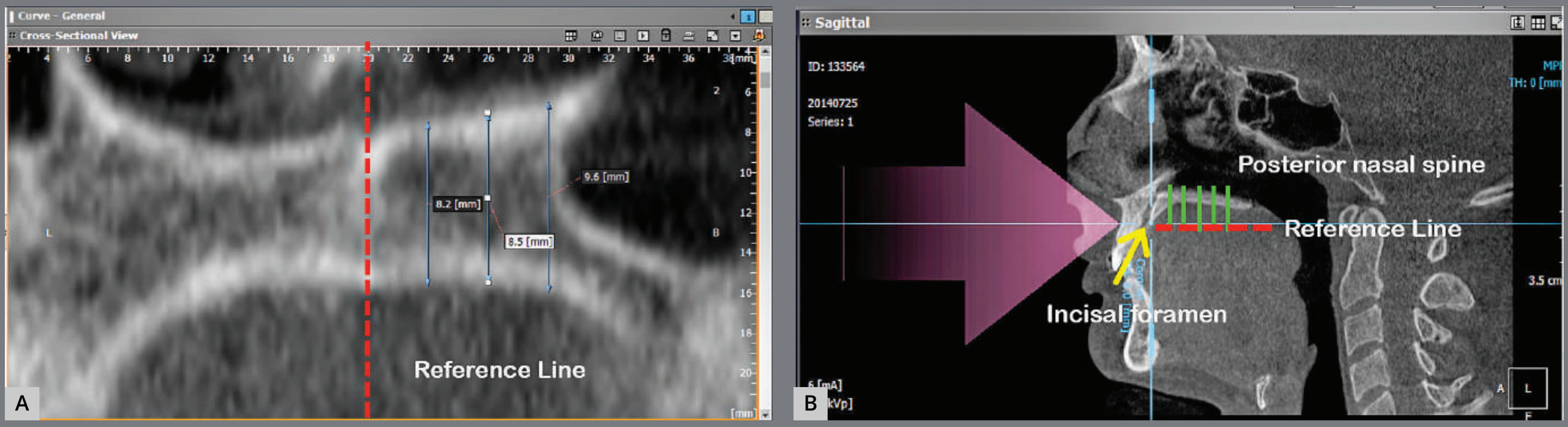

Figure 2: A) Coronal view: a reference line was constructed across the midpalatal suture. **B)** Sagittal view: a midsagittal reference line was then projected through the distal margin of the incisive foramen and PNS.

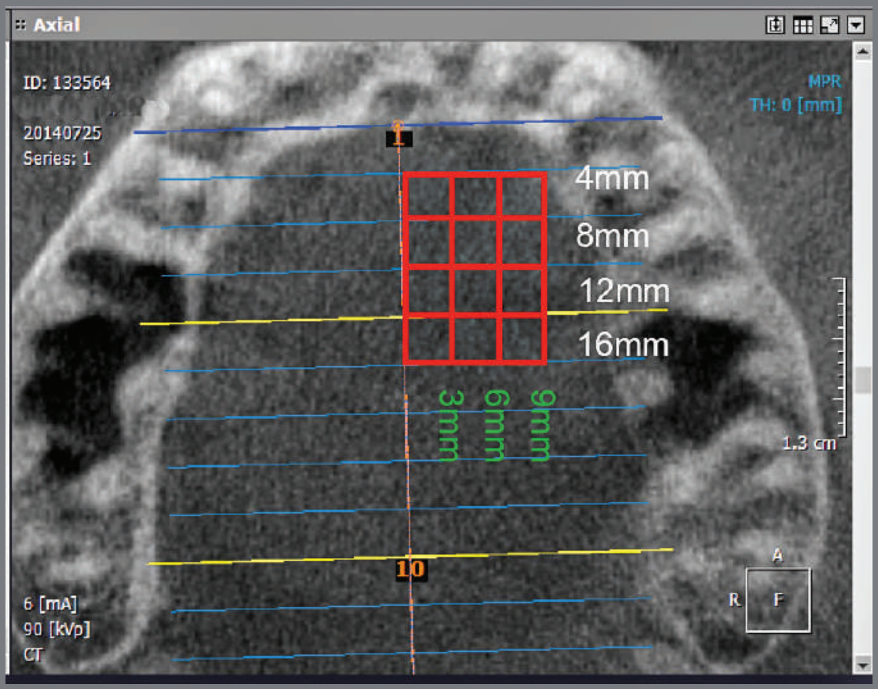

Figure 3: Measurement points at 3, 6 and 9mm lateral to midpalatal suture and 4, 8, 12 and 16mm posterior to the incisive foramen.

To evaluate the reliability of the method, the same examiner measured ten randomly selected subjects for all points, with a two week interval between trials. Intraclass correlation coefficient (ICC) was 0.92, showing an acceptable intraobserver agreement of repeated measurements. The inter-examiner reliability was evaluated between a dental radiologist and the principal examiner. Results showed a high correlation of 0.89. The results were evaluated at the significance level $p < 0.05$, with a 95% confidence interval.

The measurement error for the height and thickness of cortical palatal bone was 0.077 and 0.063mm, respectively. The measurement errors for the minimum and maximum values of cortical density of palatal bone were 35.92 and 21.69 attenuation coefficients, respectively.

The attenuation coefficient is a numerical value expressing the degree of attenuation producing body tissues on the x-ray beam. Higher values indicate high density anatomical tissues and lower values indicate low density tissue. The CBCT uses the attenuation coefficient to express the density in a grayscale. These measurements were made through an option to express the density in each CBCT, which are not standardized in the different equipment.

Statistical analysis was performed using SPSS 23 version software for Windows (IBM, Armonk, NY). Preliminary data analysis showed normal frequency distribution of the sample (Shapiro-Wick test). Descriptive statistics, ANOVA test with Tukey *post-hoc* test were used for analysis of the data at a significance level of $\alpha = 0.05$, with a 95% confidence interval, considering a test power of 80%.

RESULTS

PALATAL BONE HEIGHT

Comparison of palatal bone height measurements among the three vertical facial dimensions revealed that the hypodivergent group had the largest height values in D3/P4, D3/P8, D3/P12, D6/P12, D3/P16, D3/P20 and D6/P20, followed by the hyperdivergent and normodivergent groups (Table 2) ($p < 0.05$).

The hyperdivergent group had significantly thicker palatal height (12.21 ± 3.94mm), compared to the normodivergent group (10.09 ± 2.92mm) in one place (D9/P4) ($p < 0.05$). When comparing hyperdivergent and hypodivergent groups, statistically significant differences were found in two places (D3/P16 and D3/P20) ($p < 0.05$), with a greater height in the hypodivergent group (5.84 ± 2.49mm *vs* 5.24 ± 2.32mm).

Table 2: Average (X̄) and standard deviation (SD) of the palatal bone height, by vertical facial patterns.

DIMEN-SIONS	VERTICAL FACIAL PATTERN						
	Normodivergent	Hyperdivergent	Hypodivergent	P*	P**		
	X̄ (SD) mm	X̄ (SD) mm	X̄ (SD) mm		Normo/ Hyper	Normo/ Hypo	Hyper/ Hypo
D3/P4	7.86 (2.28)	9.23 (3.16)	9.77 (2.78)	.048	.086	.011	.525
D6/P4	8.44 (2.72)	10.12 (3.38)	10.12 (3.00)	.084	.057	.043	.996
D9/P4	10.09 (2.92)	12.21 (3.94)	11.81 (2.71)	.054	.035	.036	.675
D3/P8	5.78 (2.01)	7.01 (3.20)	8.08 (2.74)	.013	.111	.001	.208
D6/P8	6.04 (2.41)	7.26 (3.43)	8.03 (2.97)	.064	.154	.012	.400
D9/P8	7.69 (2.70)	8.92 (3.65)	9.08 (2.97)	.234	.180	.089	.869
D3/P12	4.45 (1.53)	5.48 (2.66)	6.74 (2.45)	.003	.100	.000	.086
D6/P12	4.38 (1.96)	5.24 (2.60)	6.18 (2.58)	.035	.191	.008	.210
D9/P12	5.71 (2.42)	6.81 (3.21)	7.06 (2.42)	.178	.176	.054	.759
D3/P16	3.76 (1.46)	4.30 (1.91)	5.84 (2.49)	.001	.263	.001	.018
D6/P16	3.61 (1.74)	4.24 (2.20)	4.90 (2.16)	.089	.269	.024	.287
D9/P16	4.62 (2.07)	5.33 (2.63)	5.64 (2.49)	.307	.290	.119	.668
D3/P20	3.36 (1.29)	3.54 (1.46)	5.24 (2.32)	.000	.639	.001	.003
D6/P20	3.13 (1.36)	3.15 (1.57)	4.18 (2.01)	.046	.954	.036	.050
D9/P20	3.86 (1.60)	4.25 (2.17)	4.86 (2.43)	.245	.475	.093	.356

*: ANOVA test. **: *t*-Student test. D: Lateral to midpalatal suture / P: Posterior to the incisive foramen. mm: millimeters. 3, 4, 6, 8, 9, 12, 16, 20: Distance in millimeters.

Comparing normodivergent and hypodivergent groups, the hypodivergent group obtained the largest dimensions, with statistically significant differences in D3/P4, D6/P4, D9/P4, D3/P8, D6/P8, D3/P12, D6/P12, D3/P16, D6/P16, D3/P20 and D6/P20, with an average difference of 2mm between the normodivergent and hypodivergent groups ($p < 0.05$).

CORTICAL THICKNESS (PALATAL BONE)

Statistically significant differences were observed in most locations, these being D3/P4, D6/P4, D9/P4, D3/P8, D6/P8, D3/P12, D6/P12, D3/P16, D6/P16, D9/P16 and D3/P20 ($p < 0.05$). The hypodivergent group had the largest cortical thickness of palatal bone, followed by the hyperdivergent group and finally the normodivergent group, except for D9/P16, where the hyperdivergent group was greater than the hypodivergent group (Table 3).

Table 3: Average ($\bar{X}$) and standard deviation (SD) of the cortical thickness of palatal bone, by vertical facial patterns.

DIMENSIONS	VERTICAL FACIAL PATTERN						
	Normodivergent	Hyperdivergent	Hypodivergent	P*	P**		
	$\bar{X}$ (SD) mm	$\bar{X}$ (SD) mm	$\bar{X}$ (SD) mm		Normo/ Hyper	Normo/ Hypo	Hyper/ Hypo
D3/P4	2.07 (0.54)	2.44 (0.76)	2.90 (0.87)	.001	.054	.000	.050
D6/P4	2.11 (0.66)	2.37 (0.79)	2.86 (0.79)	.003	.219	.001	.031
D9/P4	2.15 (0.64)	2.55 (1.03)	2.99 (0.75)	.003	.109	.000	.088
D3/P8	1.69 (0.45)	2.01 (0.67)	2.37 (0.70)	.001	.057	.000	.070
D6/P8	1.78 (0.55)	1.82 (0.71)	2.28 (0.71)	.015	.806	.007	.027
D9/P8	1.92 (0.56)	2.12 (0.90)	2.30 (0.78)	.216	.334	.054	.474
D3/P12	1.42 (0.33)	1.69 (0.50)	1.96 (0.39)	.000	.032	.000	.035
D6/P12	1.35 (0.40)	1.56 (0.60)	1.90 (0.53)	.001	.155	.000	.036
D9/P12	1.57 (0.46)	1.78 (0.59)	1.87 (0.46)	.104	.161	.024	.558
D3/P16	1.26 (0.51)	1.62 (0.55)	1.76 (0.39)	.002	.023	.000	.291
D6/P16	1.14 (0.45)	1.44 (0.47)	1.45 (0.37)	.021	.026	.011	.947
D9/P16	1.35 (0.48)	1.64 (0.46)	1.62 (0.38)	.040	.032	.035	.814
D3/P20	1.28 (0.51)	1.39 (0.44)	1.75 (0.42)	.002	.425	.001	.005
D6/P20	1.16 (0.45)	1.26 (0.40)	1.42 (0.27)	.056	.395	.017	.106
D9/P20	1.26 (0.46)	1.48 (0.41)	1.53 (0.43)	.071	.086	.036	.640

*: ANOVA test. **: *t*-Student test. mm: millimeters. D: Lateral to midpalatal suture / P: Posterior to the incisive foramen. 3, 4, 6, 8, 9, 12, 16, 20: Distance in millimeters.

Comparing the average values of cortical thickness of the palatal bone between the normodivergent group and the hyperdivergent group, statistically significant differences were found in D3/P12, D3/P16, D6/P16, and D9/P16 ($p < 0.05$). The hyperdivergent group had a thicker cortical plate, compared to the normodivergent group (Table 3).

The hypodivergent group had a thicker cortical plate, compared to the hyperdivergent group, with a statistically significant difference ($p < 0.05$) in D6/P4, D6/P8, D3/P12, D6/P12 and D3/P20 (Hypo, 1.75 ± 0.42mm / Hyper, 1.39 ± 0.44mm).

Comparing the average values of cortical thickness of the palatal bone between the normodivergent and hypodivergent groups, statistically significant differences ($p < 0.05$) were found in almost all places (D3/P4, D6/P4, D9/P4, D3/P8, D6/P8, D3/P12, D6/P12, D9/P12, D3/P16, D6/P16, D9/P16, D3/P20, D6/P20 and D9/P20). It was observed that the hypodivergent group has a thicker cortical (0.5mm to 1mm, in average) than the normodivergent group (Table 3).

CORTICAL DENSITY (PALATAL BONE)

No statistically significant differences were found in any of the locations indicated in the data collection sheet (Table 4 and Table 5).

Table 4: Average ($\bar{X}$) and standard deviation (SD) minimum values of the cortical density palatal bone, by vertical facial patterns.

DIMENSIONS	VERTICAL FACIAL PATTERN						
	Normodivergent	Hyperdivergent	Hypodivergent	P*	P**		
	$\bar{X}$ (SD) AC	$\bar{X}$ (SD) AC	$\bar{X}$ (SD) AC		Normo/ Hyper	Normo/ Hypo	Hyper/ Hypo
D3/P4	1262.56 (383.81)	1151.2 (440.16)	1227.84 (393.52)	.614	.345	.754	.519
D6/P4	1222.68 (392.46)	1077.76 (362.23)	1218 (393.60)	.321	.181	.967	.196
D9/P4	1246.76 (413.74)	1186.4 (417.81)	1209.92 (372.74)	.867	.610	.742	.835
D3/P8	1213.64 (391.57)	1079.12 (369.77)	1258.36 (429.70)	.259	.218	.702	.121
D6/P8	1137.68 (330.43)	1056.56 (427.11)	1193.24 (363.02)	.437	.456	.574	.229
D9/P8	1168.44 (361.66)	1141.04 (465.76)	1179.88 (416.96)	.944	.817	.918	.757
D3/P12	1199.72 (442.76)	1129.16 (463.76)	1262.32 (406.59)	.564	.585	.605	.286
D6/P12	1129.16 (427.25)	1076.48 (446.42)	1186.84 (381.61)	.650	.672	.617	.352
D9/P12	1088.84 (437.99)	1102.56 (419.26)	1133.48 (409.22)	.929	.910	.711	.793
D3/P16	1129.12 (414.20)	1134.28 (398.52)	1241.96 (395.49)	.538	.964	.329	.342
D6/P16	1127.68 (387.05)	995.4 (450.33)	1194.52 (480.46)	.274	.271	.591	.137
D9/P16	1124.6 (403.78)	1066.72 (421.44)	1161.84 (453.01)	.730	.622	.760	.446
D3/P20	1078.24 (432.33)	1133.64 (478.03)	1258.76 (403.80)	.336	.669	.134	.332
D6/P20	1075.44 (373.08)	1074.32 (468.68)	1146.56 (373.53)	.773	.993	.504	.550
D9/P20	1057.28 (398.45)	1027.04 (479.99)	1107.36 (422.44)	.805	.810	.668	.533

*: ANOVA test. **: *t*-Student test. D: Lateral to midpalatal suture / P: Posterior to the incisive foramen.
3, 4, 6, 8, 9, 12, 16, 20: Distance in millimeters. AC: Attenuation coefficient.

Table 5: Average ($\bar{X}$) and standard deviation (SD) maximum values of the cortical density palatal bone by vertical facial patterns.

DIMENSIONS	VERTICAL FACIAL PATTERN						
	Normodivergent	Hyperdivergent	Hypodivergent	P*	P**		
	$\bar{X}$ (SD) AC	$\bar{X}$ (SD) AC	$\bar{X}$ (SD) AC		Normo vs Hyper	Normo vs Hypo	Hyper vs Hypo
D3/P4	1365.68 (420.71)	1254.92 (499.94)	1341.44 (403.44)	.651	.401	.836	.504
D6/P4	1317.8 (415.63)	1179.28 (403.32)	1317.36 (400.64)	.386	.238	.997	.231
D9/P4	1333 (447.63)	1293.76 (436.77)	1271 (382.76)	.872	.238	.601	.845
D3/P8	1304.08 (386.19)	1180.76 (389.41)	1353.68 (439.03)	.306	.755	.673	.147
D6/P8	1212.32 (354.49)	1139.8 (422.48)	1288.56 (396.00)	.411	.755	.477	.205
D9/P8	1287.8 (399.10)	1252.48 (491.68)	1285.28 (420.52)	.951	.266	.983	.801
D3/P12	1308.88 (441.72)	1235.28 (468.37)	1359.96 (414.27)	.607	.266	.675	.324
D6/P12	1241.36 (441.20)	1179.88 (437.19)	1284.8 (407.69)	.687	.514	.719	.385
D9/P12	1201.44 (435.75)	1206.2 (462.81)	1232.52 (429.56)	.965	.514	.801	.836
D3/P16	1224.96 (402.44)	1242.2 (434.71)	1348.6 (431.87)	.538	.782	.300	.390
D6/P16	1223.76 (416.59)	1141.8 (458.92)	1323.12 (456.68)	.358	.782	.426	.168
D9/P16	1228.32 (416.45)	1186.96 (437.29)	1242.44 (477.07)	.900	.570	.912	.670
D3/P20	1188 (422.72)	1293.08 (501.00)	1303 (413.44)	.604	.570	.336	.939
D6/P20	1161.6 (390.77)	1218.72 (468.34)	1262.2 (420.59)	.707	.623	.385	.731
D9/P20	1197 (411.34)	1244.44 (468.09)	1179.96 (425.76)	.864	.623	.886	.613

*: ANOVA test. **: *t*-Student test. D: Lateral to midpalatal suture / P: Posterior to the incisive foramen.
3, 4, 6, 8, 9, 12, 16, 20: Distance in millimeters. AC: Attenuation coefficient.

DISCUSSION

The purpose of this study was to use CBCT to evaluate whether there is a difference in height, cortical thickness and density of the palatal bone in the different vertical facial patterns.

To evaluate the palatal bone and facial patterns, 3D images offer greater accuracy, compared with two-dimensional images, with high magnification and distorstion.[8,10,12] Also, cephalograms reconstructed from the CBCT have no statistically significant differences on linear and angular measurements in relation to the traditional cephalograms and cranial physical measurements.[14] Due to the existence of diverse studies that have demonstrated the accuracy of the CBCT, the present study used these 3D volumes for the evaluation of facial patterns and the palatal bone.[15,16]

In the present study, the hypodivergent pattern presented a higher height and greater thickness of the cortical palatal bone, compared to the normodivergent and hyperdivergent patterns. However, no statistically significant differences were found in the values of cortical density. The findings of this study could be attributed to the adaptation of the palatal bone, influenced by numerous genetic and environmental factors, which are detailed below.

PALATAL BONE HEIGHT

Several studies reported that there are statistically significant differences when comparing the height of the dentoalveolar process in the maxilla and mandible in patients with different facial patterns.[10,16-19] Sadek et al.,[10] using CBCT, reported that hyperdivergent patients had a greater dentoalveolar height in the anterior section, both in the upper and lower jaw, followed by normodivergent and finally the hypodivergent patterns.

In the present study, by measuring the height of the palatal bone, statistically significant differences were found between the facial patterns. However, the hypodivergent sample had a greater palatal bone height, followed by hyperdivergent and normodivergent patterns. Sadek et al.[10] found different results, where the dentoalveolar process in the upper and lower jaw is influenced not only by genetic factors, but also by the dentoalveolar adaptation process against different loads of oral and perioral muscle strength.[10,16-19]

For example, the tongue activity pattern during the swallowing and breathing can affect the morphological development of the palatal bone.[19]

During the process of growth and development, the palatal bone in normal situations suffers a process of remodelling, with respect to its height, due to the resorption in the nasal chambers and bone-apposition on the buccal side of the palate, suggesting that different breathing patterns (nasal or naso-buccal) could alter the height of the palatal bone.[19] These differences could affect the palatal bone dimensions, according to the Kang et al.[20] study (CBCT scans of children, 27 mouth breathers and 27 nose-breathers), who concluded that mouth breathers may have less palatal support tissues than nose breathers, because the majority of mouth breathers have a high-angle pattern in the vertical direction.

These physiological events could explain the present results, by comparing the average values of the height of the palatal bone between pairs (normo/hyper, normo/hypo and hyper/hypo), where the hypodivergent pattern had a greater palatal bone height. Similarly, Flores-Blancas et al.[21] (99 lateral cephalograms of post-pubertal individuals), found that brachifacial patterns had greater nasopharyngeal widths, compared to other vertical facial patterns, and that these changes could be influenced by the craniofacial growth pattern.

In addition, Hwang et al. [22] (CBCT scans of 101 adults aged 22 to 26 years) related the masticatory muscles and craniofacial growth. Likewise, the muscular hyperactivity of the hypodivergent patterns produces an increase in the mechanical load that would generate a greater bone apposition. On the contrary, hyperdivergent patterns show narrow and deep palates due to a weak muscular pattern.[22]

CORTICAL THICKNESS (PALATAL BONE)

Several CBCT studies reported no statistically significant differences on cortical thickness and density when these were measured on both sides of the palatal bone.[1,23-27] Baumgaertel et al.[25] (CBCT scans of 30 adults dry skulls) and Kang et al.[26] (CT records of 18 adults aged 18 to 35 years) found no significant differences between the thickness of the cortical bone on the right and left sides.

Ozdemir et al.[24] (CBCTs of 155 patients, aged 20 to 45 years) evaluated the cortical thickness of the alveolar process from the buccal side of the jaw and the palatal alveolar process in the maxilla in patients with different vertical patterns. They observed a greater cortical thickness in hypodivergent patients, compared to normodivergent and hyperdivergent patients.

There are few studies linking cortical thickness with the vertical patterns. Matsumoto et al.[27] (CTs of 31 dry skulls, aged 18 to 45 years) and Tsunori et al.[28] (CTs of 39 dry skulls of male Asiatic Indians) found no correlation between facial type and cortical thickness of the jaws.

Johari et al.[14] (CBCT of patients in permanent dentition) evaluated the relationship between the thickness of the cortical area of the mid-palatal suture and facial height. They concluded that hypodivergents had greater cortical thickness than normodivergents and hyperdivergents. They also found no statistically significant differences when comparing the normo and hyperdivergent groups, similar to the present results, which show that the hypodivergent pattern also had a greater thickness of the palatal cortical bone. However, in the Johari et al.[14] study, proportionality on the number of patients was not kept, unlike the present study, which had an equal number for each facial pattern.

CORTICAL DENSITY (PALATAL BONE)

No statistically significant differences were found in any of the vertical facial patterns.

Han et al.[9] reported a higher density of cortical and trabecular bones in adults, compared to teenagers, in CBCTs. These measurements were presented in Hounsfield units (HU), which differed from the present study, which used attenuation coefficients.

Moon et al.[11] and Han et al.[9] found a higher density in women. Furthermore, the palatal bone density tends to decrease from the anterior to the posterior area and from the midpalatal suture to the paramedian areas. No significant differences in cortical density of the palatal bone between the anterior and posterior sectors were found in the present study. Thus when comparing with Moon et al.,[11] it can be mentioned that data obtained from CT scanners cannot be extrapolated to CBCTs. Similarly, Ozdemir et al.[8] found no significant differences in the cortical density of the palatine bone between the right and left sides between the dentoalveolar buccal and palatal areas.

According to different published studies, most of these use CBCT and express the cortical density in HU, using the correct term: attenuation coefficient — the unit indicated to express the cortical density.[29,30]

Based on the results of the present study, the following clinical recommendations can be made: In patients with hypodivergent pattern, it is suggested to install TADs in the area between 4 and 12mm posterior to the incisal foramen and 3 to 9mm lateral to the middle palatal suture. This area has dimensions of maximum height and cortical thickness of 11.81mm/2.99mm respectively (canine distal approx.) and minimum cortical height and thickness of the palatal bone of 6.18mm, 1.87mm respectively (second premolar distal approx.), as seen in Figure 4.

No statistically significant differences were found in patients with normodivergent and hyperdivergent patterns, being suggested the installation of TADs in the area between 4 and 8 mm

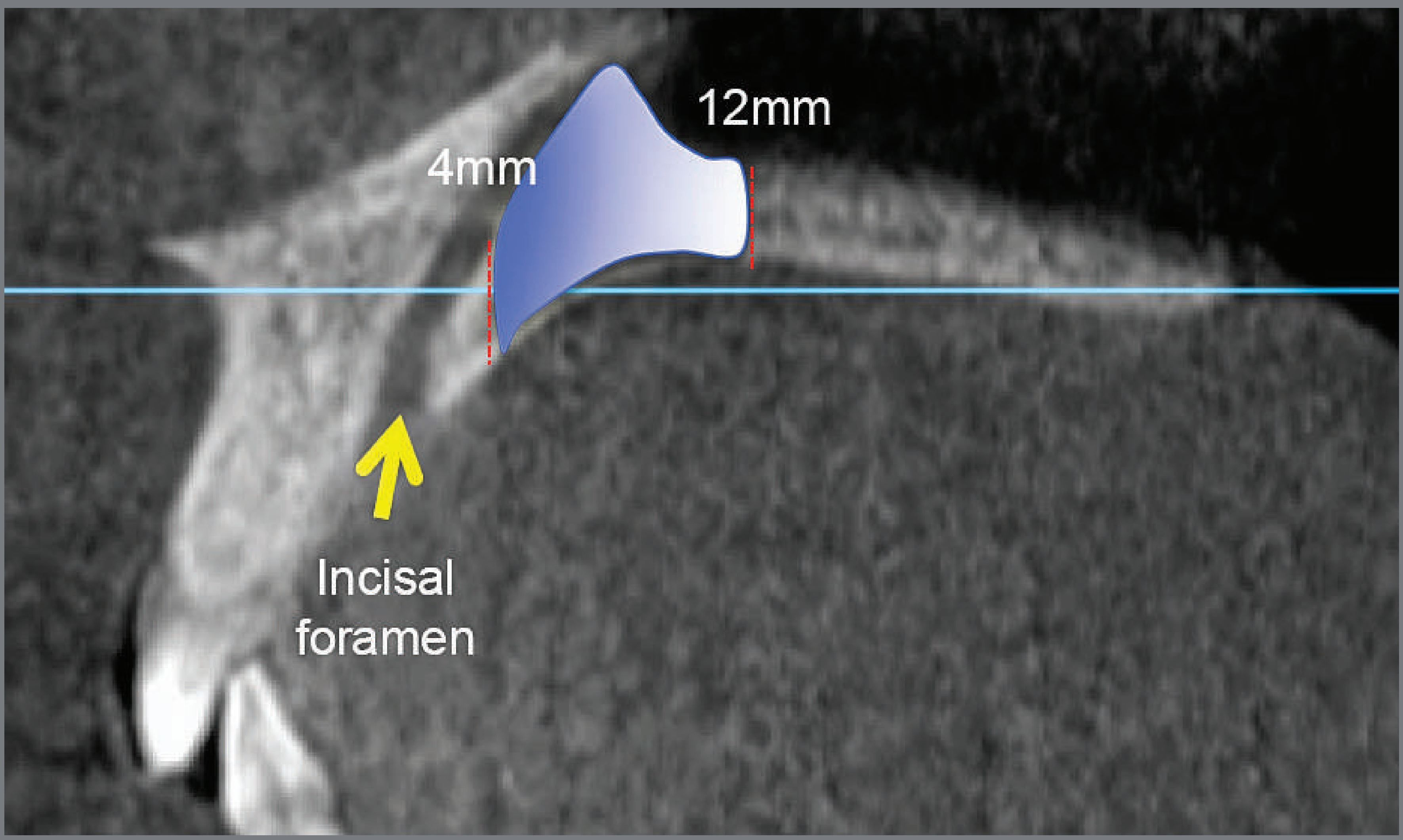

Figure 4: Hypodivergent patterns. Area between 4 and 12 mm posterior to the incisal foramen. Maximum height and cortical thickness of 11.81mm and 2.99mm, respectively (canine distal approx.), minimum cortical height and thickness of 6.18mm and 1.87mm, respectively (second premolar distal approx.).

posterior to the incisal foramen and 3 to 9mm lateral to the mid-palatal suture. This area has dimensions of maximum height and cortical thickness of 12.21mm and 1.69mm, respectively (canine distal approx.); and minimum cortical height and thickness of the palatal bone of 5.78mm and 2.55mm, respectively (first premolar distal approx.), as seen in Figure 5.

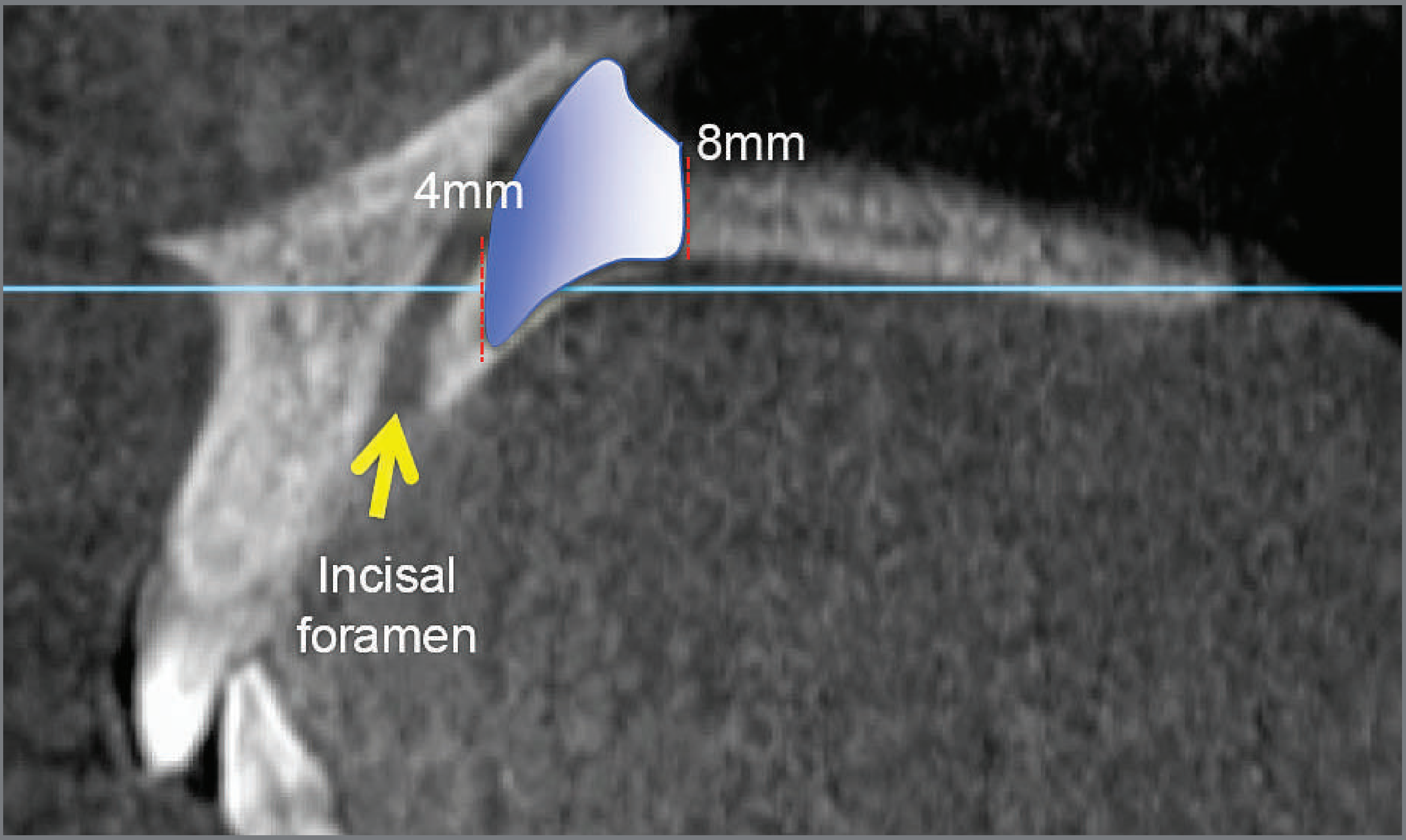

Figure 5: Normodivergent and hyperdivergent patterns. Area between 4 and 8 mm posterior to the incisal foramen. Maximum height and cortical thickness of 12.21mm and 1.69mm, respectively (canine distal approx.); minimum cortical height and thickness of 5.78mm and 2.55mm, respectively (first premolar distal approx.).

Investigations comparing the dimensions of the palatal bone and vertical facial patterns, gender and age group, are suggested as a complement to this investigation.

CONCLUSION

The palatal bone is a favorable anatomical area to install different orthodontic temporary anchorage devices (TADs) where individuals with the hypodivergent vertical facial pattern have a higher height and cortical thickness of the palatal bone, followed by the hyperdivergent pattern and finally the normodivergent pattern.

Likewise, no statistically significant differences for the cortical density of the palatal bone were found between the three vertical facial patterns.

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REFERENCES

1. Poon Y, Chang H, Tseng Y, Chou S, Cheng J, Liu P, et al. Palatal bone thickness and associated factors in adult miniscrew placements: a cone-beam computed tomography study. Kaohsiung J Med Sci. 2015;31(5):265-70.
2. Gracco A, Lombardo L, Cozzani M, Siciliani G. Quantitative cone-beam computed tomography evaluation of palatal bone thickness for orthodontic miniscrew placement. Am J Orthod Dentofacial Orthop. 2008;134(3):361-9.
3. Khademi S, Ghaffari R, Mokhtare M. Evaluation of bone thickness of hard palate for orthodontic mini implant placement by cone beam computed tomography. Indian J Sci Res. 2014;5:375-81.
4. Ludwig B, Glasl B, Bowman S, Wilmes B, Kinzinger G, Lisson J. Anatomical guidelines for miniscrew insertion: Palatal sites. J Clin Orthod. 2011;45(8):433-41.
5. Bernhart T, Um Vollgruber A, Gahleitner A, Dortbudak O, Haas R. Alternative to the median region of the palate for place- ment of an orthodontic implant. Clin Oral Implants Res. 2000;11(6):595-601.
6. Kau CH, Richmond S, Palomo JM, Hans MG. Current products and practice: three-dimensional cone beam computerized tomography in orthodontics. J Orthod. 2005;32(4):282-93.

7. Sukovic P. Cone beam computed tomography in craniofacial imaging. Orthod Craniofac Res. 2003;6(Supl. 1):31-6.

8. Ozdemir F, Tozlu M, Germec Cakan D. Quantitative evaluation of alveolar cortical bone density in adults whit different vertical facial types using cone-beam computed tomography. Korean J Orthod. 2014;44(1):36-43.

9. Han S, Bayome M, Lee J, Lee Y, Song H, Kook Y. Evaluation of palatal bone density in adults and adolescents for application of skeletal anchorage devices. Angle Orthod. 2012;82(4):625-31.

10. Sadek M, Sabet N, Hassan I. Alveolar mapping in subjects with different vertical facial dimensions. Eur J Orthod. 2015;37(2):194-201.

11. Moon SH, Park SH, Lim WH, Chun YS. Palatal bone density in adult subjects: Implications for mini-implant placement. Angle Orthod. 2010;80(1):137-44.

12. Shafey, AR. Lateral and frontal cephalometric templates and norms for Egyptian adults: reconstructed cone beam views [Master Thesis]. Cairo, EGY: Cairo University; 2011.

13. Jarabak, JR, Fizzel, JA (1972) Technique and treatment with light- wire edgewise appliance. In: Athanasios EA. Orthodontic cephalometry. St Louis, MO: Mosby-Wolfe; 1995. p. 265-6.

14. Johari M, Kaviani F, Saeedi A. Relationship between the thickness of cortical bone at maxillary mid-palatal area and facial height using CBCT. Open Dent J. 2015;9(Supl. 2):287-91.

15. Kapila S, Conley RS, Harrell Jr. WE. The current status cone beam computed tomography imaging in orthodontics. Dentomaxillofac Radiol. 2011;40(1):24-34.

16. Beckmann SH, Kuitert RB, Prahl-Andersen B, Segner D, The RP, Tuinzin DB. Alveolar and skeletal dimensions associated with lower face height. Am J Orthod Dentofacial Orthop. 1998;113(5):498-506.

17. Janson, GR, Metaxas A, Woodside DG. Variation in maxillary and mandibular molar and incisor vertical dimension in 12-year-old subjects with excess, normal, and short lower anterior face height. Am J Orthod Dentofacial Orthop. 1994;106(4):409-18.

18. Abdelali H, Benyahia H, Abouqal R, Azaroual M, Zaoui, F. Associations between alveolar heights and vertical skeletal pattern in Moroccan adults: a cephalometric study of 127 clinical cases. Int Orthod. 2012;10(1):43-53.

19. Enoki C, Telles CS, Matsumoto MA. Dental-skeletal dimensions in growing individuals with variations in the lower facial height. Braz Dent J. 2004;15(1):68-74.

20. Kang Q, Cha C, Huang D, Zuo S, Yan X. Evaluation of palatal support tissues for placement of orthodontic mini-implants in mouth breathers with high-narrow palates versus nose breathers with normal palates: a retrospective study. Clin Oral Investig. 2020;24(3):1259-67.

21. Flores-Blancas AP, Carruitero MJ, Flores-Mir C. Comparison of airway dimensions in skeletal Class I malocclusion subjects with different vertical facial patterns. Dental Press J Orthod. 2017;22(2):35-42.

22. Hwang S, Jeong S, Choi YJ, Chung CJ, Lee HS, Kim KH. Three-dimensional evaluation of dentofacial transverse widths of adults with various vertical facial patterns. Am J Orthod Dentofacial Orthop. 2018;153(5):692-700.

23. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T. Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. Am J Orthod Dentofacial Orthop. 2006;129(6):721.e7-12.

24. Ozdemir F, Tozlu M, Germec-Cakan D. Cortical bone thickness of the alveolar process measured with cone-beam computed tomography in patients with different facial types. Am J Orthod Dentofacial Orthop. 2013;143(2):190-6.

25. Baumgaertel S, Hans MG. Buccal cortical bone thickness for mini-implant placement. Am J Orthod Dentofacial Orthop. 2009;136(2):230-5.

26. Kang S, Lee SJ, Ahn SJ, Heo MS, Kim TW. Bone thickness of the palate for orthodontic mini-implant anchorage in adults. Am J Orthod Dentofacial Orthop. 2007;131(Supl. 4):S74-81.

27. Masumoto T, Hayashi I, Kawamura A, Tanaka K, Kasai K. Relationships among facial type, buccolingual molar inclination, and cortical bone thickness of the mandible. Eur J Orthod. 2001;23(1):15-23.

28. Tsunori M, Mashita M, Kasai K. Relationship between facial types and tooth and bone characteristics of the mandible obtained by CT scanning. Angle Orthod. 1998;68(6):557-62.

29. Reeves T, Mah P, McDavid WD. Deriving Hounsfield units using grey levels in cone beam CT: a clinical application. Dentomaxillofac Radiol. 2012;41(6):500-8.

30. Mah P, Reeves TE, McDavid WD. Deriving Hounsfield units using grey levels in cone beam computed tomography. Dentomaxillofac Radiol. 2010;39(6):323-35.

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Effectiveness of three different types of educational methods on implementation of proper oral hygiene behaviour prior to orthodontic treatment

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ABSTRACT

Objective: The aim of this study was to compare three teaching methods' time and personnel requirements, and their effects on plaque and gingival indices.

Methods: This study was a single-blind randomized controlled trial on fixed orthodontic appliance candidates (n = 90), assigned into a control group (n = 30) and two different study groups (n = 30 each). The control group received standard printed educational material and was assisted with verbal information. The study groups either received video-assisted or hands-on training about fixed orthodontic appliance and oral hygiene. The time requirements for all three educational interventions was recorded during the initial visit. The adequacy of oral hygiene was documented through plaque and gingival indices during the initial visit and eighth week of the treatment. The continuous variables were analyzed using 1-way ANOVA. Tukey HSD and Student *t*-tests were used for *post-hoc* comparisons ($\alpha = 0.05$). Also, a chi-square test was used for the analysis of categorical variables.

Results: Standard education failed to maintain the plaque and gingival indices at the eighth week of the treatment. Although both video-assisted and hands-on training took a considerable amount of time, they served well in preserving both of the indices at the eighth week. The longer the educational intervention was, the better the preservation of the plaque and gingival indices.

Conclusion: Educational intervention, either with video-assisted or hands-on programs, provided better results in oral hygiene depending on the time and personnel constraints of the orthodontist.

Keywords: Orthodontic appliances. Oral hygiene. Oral health training.

RESUMO

Objetivo: O objetivo do presente estudo foi comparar o tempo necessário e os pré-requisitos de equipe de três diferentes métodos de orientação ao paciente, e seus efeitos sobre os índices de placa e gengival.

Métodos: Esse foi um estudo controlado aleatório cego em candidatos (n=90) a tratamento ortodôntico fixo, que foram divididos em um grupo controle (n=30) e dois grupos de estudo (n= 30 cada). O grupo controle recebeu material educacional impresso e foi orientado com informações verbais. Os grupos de estudo receberam treinamento em formato de vídeo ou treinamento *hands-on* sobre higiene bucal e sobre o tratamento com Ortodontia fixa. O tempo necessário para realizar cada um dos três tipos de treinamento foi registrado durante a consulta inicial. A qualidade da higiene bucal foi avaliada por meio dos índices de placa e gengival durante a consulta inicial e após oito semanas de tratamento. As variáveis contínuas foram analisadas utilizando-se o ANOVA de uma via. Os testes HSD de Tukey e *t* de Student foram utilizados para comparações *post-hoc* ($\alpha = 0{,}05$), e o teste qui-quadrado foi utilizado para análise das variáveis categóricas.

Resultados: O método convencional de treinamento fracassou em manter os índices de placa e gengival até a oitava semana de tratamento. Apesar de tanto o método de treinamento com vídeos e de treinamento *hands-on* demandarem um tempo considerável, eles conseguiram manter ambos os índices até a oitava semana. Quanto mais longo o treinamento realizado, melhor foi a manutenção dos índices de placa e gengival.

Conclusão: Tanto o método de treinamento com vídeo quanto no formato *hands-on* obtiveram melhores resultados de higiene bucal, mas dependem do tempo e das limitações de equipe de cada ortodontista.

Palavras-chave: Aparelho ortodôntico. Higiene bucal. Treinamento em saúde bucal.

INTRODUCTION

Orthodontic treatment using fixed orthodontic appliances that prevent patients from effectively cleaning their teeth results in increased plaque formation and deterioration of oral hygiene.[1] Inappropriate oral hygiene behaviour during the fixed orthodontic appliance treatment causes gingival enlargement, gingivitis, enamel decalcification and white spots in the vicinity of the applied therapeutic material in 50-70% of patients with fixed appliances.[1-5] Also, inappropriate oral hygiene has been shown to prolong the treatment duration and may result in poor treatment outcomes.[6] Of all the orthodontic treatments, 5-10% fail because of inappropriate oral hygiene caused by patient incompliance.[7] For these reasons, proper oral hygiene behaviour is of great importance to the treatment period of almost two years. Oral hygiene can only be achieved through patient compliance, which is built up through communication between the orthodontist, the patient and the family by means of verbal and written educational material.[8] Routine oral hygiene instruction given to the patients by the orthodontist may be insufficient to provide proper oral hygiene.[5,6]

The implementation of oral hygiene in fixed orthodontic appliance treatment candidates through verbal, written and visual information materials has been evaluated in a couple of studies. They either calculated the ratio of disclosed plaque,[9-12] or plaque and gingival indices[13-15] were objectively used in order to evaluate the implementation of learned information. In these studies, plaque disclosing — one of the methods of oral hygiene motivation — has been shown to increase the patient's motivation through visualization and presentation.[11,12] However, the messages delivered through text, WhatsApp, etc. indicate that motivation is effective in patients' oral hygiene motivation,[14,16] and even better than plaque disclosing tablets.[10] Studies comparing the effectiveness of different oral hygiene training methods found that video-assisted and hands-on training have also been effective approaches.[15,17] In recent reviews, motivational approaches with the potential to make more behavioural changes than traditional health education have been found to have different effects on success rates.[18,19] However, motivation of patients through various methods plays a crucial part in maintaining proper oral hygiene.

In all of these studies, different methods of implementing the proper oral hygiene were evaluated only for their effectiveness. As education is the most important part of building rapport between the clinician and patient, it is also a time and effort-consuming process. Moreover, it may not be as fruitful as expected due to patient compliance problems.[19] Patient motivation and willingness to persist with lifestyle changes are prone to wear out as they require constant effort on the patients' behalf to change improper but ingrained habits.

The two possible restrictions influencing the transfer of information —either positively or negatively— to any patient are time and personnel requirements in busy orthodontic clinics, which have not been addressed in previous studies.

Therefore, the aim of this study was to compare the time requirements of three types of information transfer techniques, which were all proven to be effective to different degrees in improving oral hygiene in fixed orthodontic appliance treatment candidates.[18,19] We have also documented the effectiveness rate for each method through plaque and gingival indices. The first null hypothesis was that none of the oral hygiene education methods would affect oral hygiene. The second null hypothesis was that there is no difference in duration of oral hygiene adoption either with video-assisted or hands-on training.

MATERIAL AND METHODS

This study is a randomized controlled three-arm parallel trial performed on a group of patients who applied to the outpatient clinic of Orthodontics at the Faculty of Dentistry of Bulent Ecevit University on November 11th, 2014. We collected a total of 90 patients (mean=14.73±2.63, 10-24 years old) who were undergoing fixed orthodontic treatment after meeting eligibility criteria (Fig 1). According to calculations made with Piface (version 1.76), the minimum sample size that would guarantee power equal to 0.82 was 30 for each of the three groups (α=0.05, SD= 6.61).

The study was approved by the ethical committee for human research at the Faculty of Medicine (decision number 2014103, made on 11 February, 2014) at Bulent Ecevit University. All of the participants or their legal representatives gave their informed consent prior to educational intervention. Also, the trial was registered with the ClinicalTrials.gov, supported by the U.S. National Library of Medicine (NCT04018534).

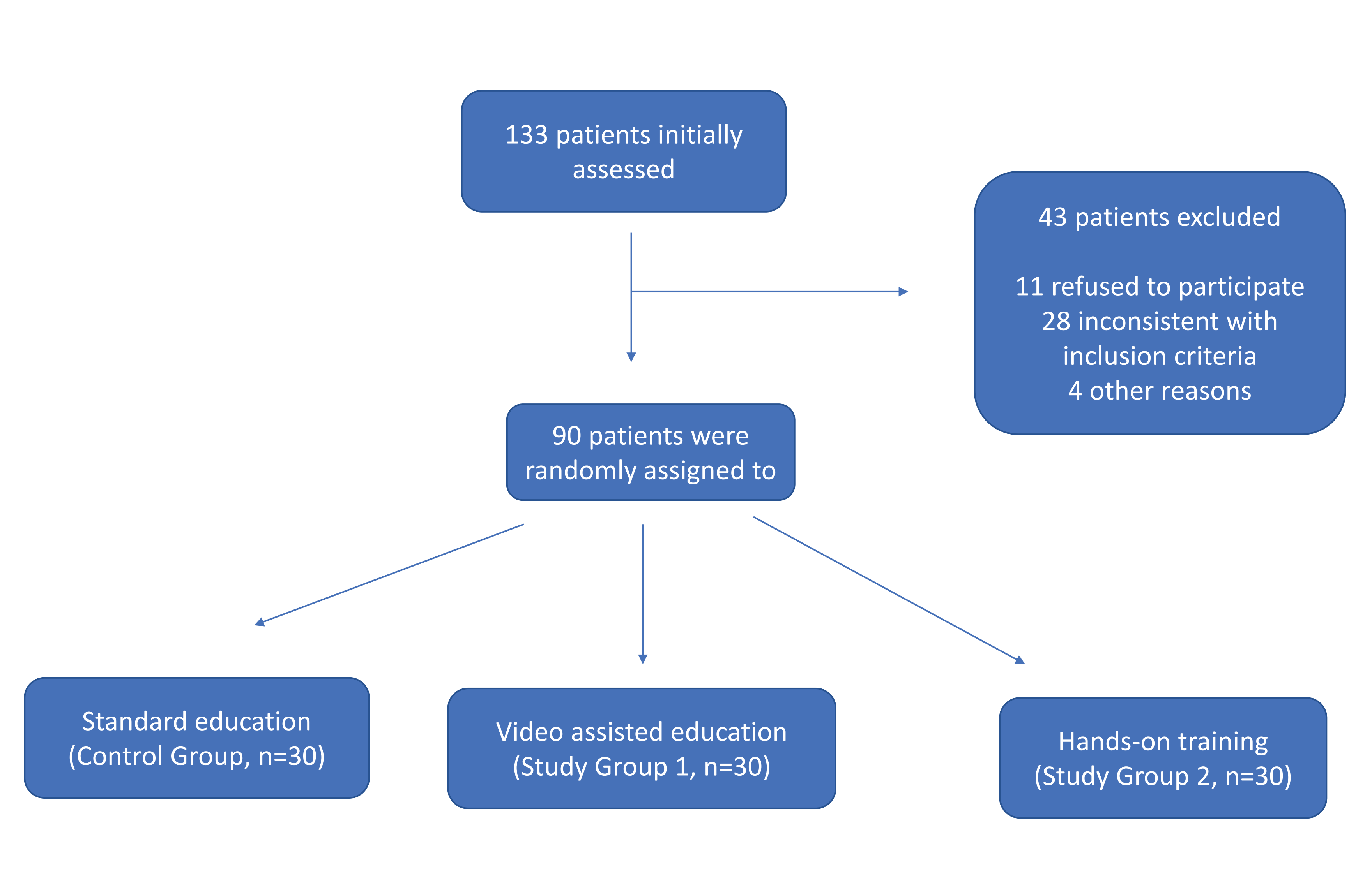

Figure 1: Flow chart of study, selection of patients and arrangement of trial.

Thirty patients were selected according to the following inclusion criteria: they required non-extraction fixed orthodontic treatment, agreed to use conventional stainless steel brackets (Gemini series, 3M Unitek, Monrovia, California, USA), had at least 20 natural permanent teeth, crowding under 5mm in the incisors, and were willing to participate in this research. The exclusion criteria were as follows: having dental caries, periodontal disease, systemic or chronic diseases such as diabetes, physical or mental disorders, smoking, having undergone previous orthodontic treatment, extensive dental restorations, antibiotic use during the previous three months, dental fluorosis and use of electric toothbrushes.

This study was conducted as a single-blind, randomized clinical trial. A computer program (research randomizer) was used to randomly allocate each patient to one of three groups. To avoid bias, random sequencing was performed by one of the authors, who had not taken part in allocation or by the measurement statistician. Another author explained the study and introduced oral hygiene to the patients and their guardians according to random sequencing, which was provided in opaque, sealed envelopes during the first appointment. Also, the investigator who treated patients and collected data was blinded to all groups throughout the study.

All the participants were referred to the department of Periodontology for plaque elimination, prior to orthodontic treatment. The educational goals in all of the educational interventions were consistent with the goals mentioned in the educational booklet of British Orthodontics Society (BOS) about oral hygiene (Table 1).[20]

Ninety consecutive fixed orthodontic appliance treatment candidates in compliance with the above-mentioned criteria were randomly assigned to three groups (n = 30 in each):

Table 1: Learning objectives for oral hygiene education and components of fixed orthodontic appliance. Source: Thickett and Newton,[20] 2006.

Learning objectives for oral hygiene education	Learning objectives for components of fixed appliance treatment
The equipment required for orthodontic oral care.	What are the components of oral fixed appliance therapy?
How do I use an orthodontic tooth brush?	The obligation for hygiene of the molar bands and molar tubes in every oral care episode.
How do I use an interspace brush?	What are the names of the two fixed appliance components to be checked at the end of daily oral care?
How do I use an ordinary tooth brush?	What should I do when my brackets are removed or my archwire is broken?
How do I use dental floss?	What precaution should I take in case of irritation caused by the brackets and molar tubes?
How do I use fluorinated mouthwash?	What are the basic rules when using elastics?
What are the names of the two fixed appliance components to be checked at the end of daily oral care?	What should I do in case of pain due to the appliance?
What kind of food do I have to avoid?	What is the duration of the therapy?
	What is the frequency of orthodontic appointments?
	Is it safe to attend sports activities?
	Is it safe to play any musical instrument?

Control group (CG): The patients in the control group received standard printed educational material and were assisted with verbal information in accordance with BOS educational goals.[20]

Study group 1 (S1): The patients in this study group received video-assisted information (Fig 2).

Study group 2 (S2): The patients in this study group received hands-on training.

Both video and hands-on assisted training sessions covered a set of knowledge and skills on fixed appliance therapeutic devices and oral hygiene, as stated in the educational booklet of BOS (Table 1).[20] The primary outcomes were the plaque and gingival indices.

Figure 2: Sections from video-assisted education.

Table 2: Patient demographics, baseline characteristics and initial periodontal health conditions (n=30 per group).

Variables	CG	S1	S2	P
Age (Years)	15.5±3.1	14.0±2.3	14.7±2.3	
<18 years (n,%)	26 (87)	29 (97)	28 (93)	0.11†
≥18 years (n,%)	4 (13)	1 (3)	2 (7)	
Gender				
Male (n,%)	7 (23)	11 (37)	12 (40)	0.35‡
Female (n,%)	23 (77)	19 (72)	18 (60)	
Initial PI	0.49±0.34	0.39±0.37	0.50±0.26	0.39†
Initial GI	0.49±0.30	0.38±0.26	0.45±0.30	0.28†

CG, Control Group (Standard education); S1, Study Group 1 (Video-assisted education); S2, Study Group 2 (Hands-on training) ; PI, Plaque Index; GI, Gingival Index; † One way analysis of variance, ‡ Kruskall-Wallis analysis of variance. 95% Confidence Interval for Mean, $p < 0.05$, significant difference.

The importance of eliminating dental plaque in oral health was emphasized and oral hygiene instructions were repeated by the same author during each appointment. Patients in all groups used the same kind of toothbrush and toothpaste throughout the study and were advised to brush their teeth at least three times a day for three minutes. The brushing habits of the patients were checked during each appointment and the orthodontic archwires were ligated with stainless steel wires.

The video-assisted training consisted of two separate sessions, each one lasting five minutes. The first was about the treatment materials and the second about oral hygiene, in compliance with the BOS educational obligations. All the candidates were allowed to rewind and watch the video presentation until they reached all of the educational goals. The completion of the educational goals was documented through a written examination form filled by the candidates themselves. They all got the full score in the written examinations in both topics.

The hands-on training, consisting of two separate sessions, was performed by one of the authors. The first was about the treatment materials and the second about oral hygiene, in accordance with the BOS educational obligations. All of the patients were allowed to ask questions freely until they reached all of the educational goals. The completion of the goals was documented through a written examination form filled by the candidates themselves. They all got the full score in the written examinations in both topics. The time requirements for the three different educational interventions were recorded separately.

The adequacy of oral hygiene was documented through the Löe and Silness[21] plaque and gingival indices, by one of the authors, who was blinded to the patients' educational intervention group during the initial visit and the eighth week of the treatment.

STATISTICAL ANALYSIS

The statistical analysis was performed by using SPSS 25.0 (IBM Corporation, Armonk, NY, USA). The suitability of the data to normal distribution was assessed with the Shapiro-Wilk test (95% confidence intervals for means). The continuous variables were presented as mean ± standard deviation (SD); and categorical variables, in frequency and percentage. The group comparisons for continuous variables were performed using one-way analysis of variance (ANOVA). Also, Tukey HSD and Student *t*-test were used for *post-hoc* comparisons ($\alpha = 0.05$). The group comparisons for categorical variables were performed using a chi-square test. The correlation between variables was analyzed using the Pearson correlation coefficient, and *p* values lower than 0.05 were accepted as significant in all the tests.

RESULTS

All of the patients in the control and study groups were comparable regarding age, gender and initial plaque and gingival indices values ($p > 0.05$) (Table 2). The time duration for standard educational intervention was 13.5 ± 2.2 min, while video-assisted education took 38.7 ± 8.0 min and hands-on training was 25.2 ± 6.5 min. These time durations consisted of the education time needed for both fixed appliance components and oral hygiene education. The mean total time duration for the educational intervention was found to be significantly shorter in the control group when compared with those of both study groups (*p* < 0.001) (Table 3). The mean time for video-assisted education was significantly longer than that of the hands-on training group (*p* < 0.001) (Table 4).

The two study groups did not show any significant intergroup or in-group deterioration regarding plaque and gingival indices at the initial eighth week examinations (*p* > 0.05) (Table 4). However, the eighth week plaque and gingival indices in

Table 3: Comparison of mean PI, GI and instruction times of different educational methods (n=30 per group).

Variable	Group	Mean± SD	df	F	P	Estimated effect size
Initial PI	CG	0.49±0.34[A]	2	0.96	0.39†	0.02
	S1	0.40±0.37[A]				
	S2	0.51±0.26[A]				
Eighth week PI	GC	0.97±0.40[B]	2	42.91	< 0.001†	0.5
	S1	0.41±0.14[A]				
	S2	0.41±0.21[A]				
Initial GI	GC	0.50±0.30[A]	2	1.30	0.28†	0.03
	S1	0.38±0.26[A]				
	S2	0.44±0.30[A]				
Eighth week GI	GC	1.19±0.20[B]	2	122.29	< 0.001†	0.74
	S1	0.36±0.26[A]				
	S2	0.45±0.20[A]				
Total time for education (min)	GC	13.53±2.19[A]	2	128.17	< 0.001†	0.75
	S1	25.17±6.47[B]				
	S2	38.70±8.04[C]				

CG, Control Group (Standard education); S1, Study Group 1 (Video-assisted education); S2, Study Group 2 (Hands-on training); PI, Plaque Index; GI, Gingival Index; SD, Standard deviation; df, numerator degrees of freedom. Different superscript letters denote significant differences according to Tukey HSD post-hoc test.
† One-way analysis of variance. 95% Confidence Interval for Mean, *p* < 0.05, significant difference.

Table 4: The comparison of the study groups for duration of education, plaque index and gingival index (n=30 per group).

Variables	S1		S2		F	df	P
	Mean± SD	SE	Mean± SD	SE			
Initial PI	0.40±0.37	0.07	0.51±0.26	0.05	0.07	58	0.188†
Eighth week PI	0.41±0.14	0.03	0.41±0.21	0.04	2.75	58	0.972†
Initial GI	0.38±0.26	0.05	0.44±0.30	0.05	0.15	58	0.336†
Eighth week GI	0.36±0.26	0.05	0.45±0.20	0.04	0.96	58	0.171†
Total time for education (min)	25.17±6.47	1.18	38.70±8.04	1.47	2.48	58	<0.001†

S1, Study Group 1 (Video-assisted education); S2, Study Group 2 (Hands-on training); PI, Plaque Index; GI, Gingival Index; SD, Standard deviation; SE, Standard Error; †Student t-test; 95% Confidence Interval for Mean, $p < 0.05$, significant difference.

the control group patients significantly deteriorated when compared with the initial index values ($p < 0.001$) (Table 3). The eighth week plaque and gingival indices of the control group were also significantly poorer than those of the two study groups ($p < 0.001$) (Table 3).

The time duration spent on patient education was found to be inversely and strongly correlated with the preservation rate of the plaque and gingival indices. The longer the duration of education — including both fixed appliance treatment components and oral hygiene — the better the preservation rate of the plaque index (r = -0.535, $p < 0.001$) and gingival index (r = -0.561, $p < 0.001$) in the eighth week of treatment.

DISCUSSION

In this study, plaque and gingival indices of patients receiving different educational methods were compared in the eighth week of treatment. The plaque index values of the three groups was significantly affected by different educational methods ($p < 0.05$). Therefore, the first null hypothesis was accepted. In addition, the training time of the video-assisted and hands-on methods were examined separately. The video training method took less time than the hands-on method ($p < 0.05$). Therefore, the second null hypothesis was rejected.

The present study investigated the success and clinical efficacy of different educational interventions on oral hygiene motivation in individuals undergoing fixed orthodontic treatment. This is because fixed appliance treatment is known for its deleterious effects, such as gingivitis, white spots, decalcification and cavity formation unless oral hygiene is maintained by the patients themselves.[22-25] The institution of oral hygiene before the onset of orthodontic treatment is recommended as an effective means against development of the above-mentioned complications.[17] As it becomes more difficult to sustain oral hygiene following the application of therapeutic appliances,[26] the educational intervention for oral hygiene behaviour and the orthodontic treatment materials take priority in the beginning of the treatment.[17] The only known and successful way for achieving desired oral hygiene is both educating the patient prior to the treatment and building rapport between doctor and patient during the long-term treatment.[8]

The effectiveness of different methods in improving oral hygiene compliance of patients undergoing fixed orthodontic treatment to minimize these harmful effects has been investigated in previous studies. Since orthodontists worry that patients' compliance will decrease during the 4-6 week appointment intervals of the treatment,[19] the patients were motivated by a number of reminder messages or applications (text, WhatsApp, WeChat) that emphasized the importance of good oral hygiene, and the effectiveness of these reminders was investigated. In all of these studies, it was stated that the use of reminders in dentistry improved the patient's out-clinical management, regular attendance of appointments, positive behaviour changes and educational factors.[10,14,16,27] However, many smartphones have the ability to block messages and they can be easily blocked if they cause annoyance to patients.[19] In addition, it has been emphasized in studies that plaque disclosing tablets increase oral hygiene motivation through visualization of plaque accumulation.[11,12] Although it is easily accessible and practiced in orthodontic clinics, its use may be limited due to its price, especially in developing and underdeveloped countries.[19]

Although the above-mentioned oral hygiene motivations were less time-consuming per patient, we tested educational interventions, which are more widely accepted by orthodontic patients and have become a long-term habit. Patient education on oral hygiene behaviour was found to be successful either through verbal, written or visual educational interventions.[8-11] These techniques have been proven to be more effective when used in combination rather than independently.[8] It is also known that hands-on training together with verbal and written educational means improves the success rates in plaque and gingival indices preservation during orthodontic treatment.[15]

The main purpose of the present study was to compare the time duration spent on educational interventions through three different modes of information transfer, and to evaluate its relation with positive outcomes in plaque and gingival indices. In addition, the effectiveness of the standard, video-assisted and hands-on education techniques were also compared. The study showed that both study groups succeeded in maintaining oral hygiene without any significant difference between the preservation rates of plaque and gingival indices ($p > 0.05$). Although both video and hands-on training assisted educations took a considerable amount of time for the orthodontist, the time duration of hands-on education was found to be significantly shorter than that of video-assisted education ($p < 0.001$). This may provide the orthodontist two options to choose from: either a time-consuming option (video-assisted) or an effort consuming (hands-on assisted) method, depending on their constraints. On the other hand, the control group, which received standard educational intervention, failed to preserve oral hygiene, at least at the eighth week of treatment.

Although it is time and effort-consuming, the video and hands-on assisted educational techniques are seemingly more desirable for preserving plaque and gingival indices ($p < 0.001$), hence preventing various complications from the treatment. The oral hygiene education covered topics such as the names of the therapeutic appliances, the maintenance of these materials and the effective use of oral hygiene tools. Patients had to remember in full and properly apply this information after the educational intervention. In addition, they had to overcome their powerful and negative urges and implicit behavioural retreat from oral hygiene. The motivation of the orthodontist in implementing oral hygiene through educational intervention is important for the patients to understand and behave according with oral hygiene precautions. Repetition of the topics related to oral hygiene during successive appointments is also recommended.[28]

The first limitation of the study was the Hawthorne effect,[9] which resulted from the inability to blind patients. It was not possible to eliminate this because of the consent form obtained from patients and their parents for participation in the study. The second limitation was that the follow-up period of the patients was limited to eight weeks and long-term follow-up was not managed. However, this lack can be considered normal as we focus on training durations rather than the success of oral hygiene motivation in planning our study.

CONCLUSION

In a couple of previous studies, the provision of oral hygiene behaviour education by orthodontists or oral hygienists was emphasized.[9-11,13,14] However, the time and personnel constraints were not addressed in those studies. We found that standard verbal and written educational interventions are better supported by either video or hands-on assisted educational programs depending on the constraints of the orthodontist. The longer the educational intervention is, the better the preservation of the plaque and gingival indices. Presumably, the orthodontists may help their patients with a safer therapeutic approach by providing them with a longer duration of education either by making them view video recordings in the waiting room or letting them perform hands-on training about proper orthodontic oral hygiene and fixed appliance treatment, under the supervision of a dental hygienist.

AUTHORS' CONTRIBUTION

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Conception or design of the study:

FCO, EA.

Writing the article:

FCO, EA, HY, EIK.

Data acquisition, analysis or interpretation:

FCO, EA, HY, EIK.

Critical revision of the article:

FCO, EA, HY, EIK.

Final approval of the article:

FCO, EA, HY, EIK.

Fundraising:

FCO.

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REFERENCES

1. O'Reilly M, Featherstone J. Demineralization and remineralization around orthodontic appliances: an in vivo study. Am J Orthod Dentofacial Orthop. 1987;92(1):33-40.
2. Arends J, Christoffersen J. Invited review article: the nature of early caries lesions in enamel. J Dent Res. 1986;65(1):2-11.
3. Richter AE, Arruda AO, Peters MC, Sohn W. Incidence of caries lesions among patients treated with comprehensive orthodontics. Am J Orthod Dentofacial Orthop. 2011;139(5):657-64.
4. Zachrisson BU. Clinical experience with direct-bonded orthodontic retainers. Am J Orthod. 1977;71(4):440-8.
5. Palomares NB, Celeste RK, Oliveira BH, Miguel JAM. How does orthodontic treatment affect young adults' oral health-related quality of life? Am J Orthod Dentofacial Orthop. 2012;141(6):751-8.
6. Skidmore KJ, Brook KJ, Thomson WM, Harding WJ. Factors influencing treatment time in orthodontic patients. Am J Orthod Dentofacial Orthop. 2006;129(2):230-8.
7. Mehra T, Nanda R, Sinha P. Orthodontists' assessment and management of patient compliance. Angle Orthod. 1998;68(2):115-22.

8. Thomson AM, Cunningham SJ, Hunt NP. A comparison of information retention at an initial orthodontic consultation. Eur J Orthod. 2001;23(2):169-78.

9. Feil PH, Grauer JS, Gadbury-Amyot CC, Kula K, McCunniff MD. Intentional use of the Hawthorne effect to improve oral hygiene compliance in orthodontic patients. J Dent Educ. 2002;66(10):1129-35.

10. Brent Bowen T, Rinchuse DJ, Zullo T, DeMaria ME. The influence of text messaging on oral hygiene effectiveness. Angle Orthod. 2014;85(4):543-8.

11. Acharya S, Goyal A, Utreja AK, Mohanty U. Effect of three different motivational techniques on oral hygiene and gingival health of patients undergoing multibracketed orthodontics. Angle Orthod. 2011;81(5):884-8.

12. Peng Y, Wu R, Qu W, Wu W, Chen J, Fang J, et al. Effect of visual method vs plaque disclosure in enhancing oral hygiene in adolescents and young adults: a single-blind randomized controlled trial. Am J Orthod Dentofacial Orthop. 2014;145(3):280-6.

13. Marini I, Bortolotti F, Parenti SI, Gatto MR, Bonetti GA. Combined effects of repeated oral hygiene motivation and type of toothbrush on orthodontic patients: a blind randomized clinical trial. Angle Orthod. 2014;84(5):896-901.

14. Zotti F, Dalessandri D, Salgarello S, Piancino M, Bonetti S, Visconti L, et al. Usefulness of an app in improving oral hygiene compliance in adolescent orthodontic patients. Angle Orthod. 2015;86(1):101-7.

15. Ay ZY, Sayın M, Özat Y, Goster T, Atilla AO, Bozkurt FY. Appropriate oral hygiene motivation method for patients with fixed appliances. Angle Orthod. 2007;77(6):1085-89.

16. Eppright M, Shroff B, Best AM, Barcoma E, Lindauer SJ. Influence of active reminders on oral hygiene compliance in orthodontic patients. Angle Orthod. 2013;84(2):208-13.

17. Lees A, Rock W. A comparison between written, verbal, and videotape oral hygiene instruction for patients with fixed appliances. Br J Orthod. 2000;27(4):323-8.

18. Gao X, Lo ECM, Kot SCC, Chan KCW. Motivational interviewing in improving oral health: a systematic review of randomized controlled trials. J Periodontol. 2014;85(3):426-37.

19. Huang J, Yao Y, Jiang J, Li C. Effects of motivational methods on oral hygiene of orthodontic patients: A systematic review and meta-analysis. Medicine. 2018;97(47):e13182.

20. Thickett E, Newton JT. Using written material to support recall of orthodontic information: a comparison of three methods. Angle Orthod. 2006;76(2):243-50.

21. Löe H, Silness J. Periodontal disease in pregnancy I. Prevalence and severity. Acta Odontol Scand. 1963;21(6):533-51.

22. Mitchell L. Decalcification during orthodontic treatment with fixed appliances—an overview. Br J Orthod. 1992;19(3):199-205.

23. Zaghrisson BU, Zachrisson S. Caries incidence and oral hygiene during orthodontic treatment. Eur J Oral Sci. 1971;79(4):394-401.

24. Alexander SA. Effects of orthodontic attachments on the gingival health of permanent second molars. Am J Orthod Dentofacial Orthop. 1991;100(4):337-40.

25. Gorelick L, Geiger AM, Gwinnett AJ. Incidence of white spot formation after bonding and banding. Am J Orthod. 1982;81(2):93-98.

26. Ciancio D. A comparison of plaque accumulation in bonded versus banded teeth. J Dent Res. 1985;64:325.

27. Li X, Xu Z-R, Tang N, Ye C, Zhu X-L, Zhou T, et al. Effect of intervention using a messaging app on compliance and duration of treatment in orthodontic patients. Clin Oral Investig. 2016;20(8):1849-59.

28. Clark JR. Oral hygiene in the orthodontic practice: Motivation, responsibilities, and concepts. Am J Orthod Dentofacial Orthop. 1976;69(1):72-82.

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Conservative treatment in adult patient with reimplanted anterior teeth after traumatic avulsion with extensive bone loss: an 8-year follow-up

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ABSTRACT

Introduction: Orthodontic treatment in patients with traumatized teeth is a condition that needs good planning in order to achieve satisfactory results.

Objective: To discuss approaches to orthodontic treatment of malocclusions associated with trauma followed by avulsion of anterior teeth, reimplanted after a short period of time.

Case report: The treatment started with the distalization of upper posterior teeth, with the aid of mini-implants and sliding jigs, followed by the inclusion of anterior teeth in the arch, followed by intrusion of these teeth.

Results: With the treatment, improved mobility of the anterior teeth was achieved, with better insertion into bone tissue. The most important factor for satisfactory treatment and a good prognosis for avulsion is the time the tooth remains outside the socket. Orthodontic treatment in patients with traumatized teeth is not contraindicated; however, clinical and radiographic aspects must be considered.

Conclusion: Among the feasible orthodontic treatment options, the conservative approach can be a very favorable treatment alternative.

Keywords: Conservative treatment. Tooth injuries. Periodontal diseases. Orthodontic anchorage procedures. Adult.

RESUMO

Introdução: O tratamento ortodôntico em pacientes com dentes traumatizados é uma condição que necessita de um bom planejamento, a fim de se conseguir resultados satisfatórios.

Objetivo: Discutir as abordagens de tratamento ortodôntico de más oclusões associadas ao trauma seguido de avulsão de dentes anteriores, reimplantados após curto espaço de tempo.

Relato do Caso: O tratamento realizado iniciou-se com a distalização dos dentes posteriores superiores, com auxílio de mini-implantes e *sliding jigs*, seguida da inclusão dos dentes anteriores na arcada e intrusão desses dentes.

Resultados: Com a realização do tratamento, conseguiu-se melhoria na mobilidade dos dentes anteriores, com inserção mais favorável no tecido ósseo. O fator mais importante para o tratamento satisfatório e um bom prognóstico da avulsão é o tempo em que o dente permanece fora do alvéolo. O tratamento ortodôntico em pacientes com dentes traumatizados não é contraindicado; porém, aspectos clínicos e radiográficos devem ser considerados.

Conclusão: Entre as opções de tratamento ortodôntico factíveis, a abordagem conservadora pode ser uma opção de tratamento bastante favorável.

Palavras-chave: Tratamento conservador. Injúrias dentárias. Doença periodontal. Procedimentos de ancoragem ortodôntica. Adulto.

INTRODUCTION

The number of adult patients who seek orthodontic treatment increases every day.[1] Advancements in esthetics and comfort of orthodontic appliances has boosted the demand for this treatment.[2,3] Adult patients have some peculiarities that are inherent to their past history that make their treatment unique.[4,5] Missing teeth, periodontal disease, and traumatized teeth are not uncommon among these patients.[6]

Traumatic injuries to permanent incisors and their supporting structures constitute a true dental emergency and require immediate assessment and management.[7] Among traumatic dental injuries, avulsion is one of the most severe, and its prognosis is closely related to the actions taken from immediately after avulsion to tooth reimplantation.[8,9]

Tooth reimplantation is considered a conservative treatment aimed at reinserting the avulsed tooth into the socket, but several factors should be taken into account in order to achieve an acceptable outcome.[10] Time out of the socket is the most important factor for satisfactory treatment of avulsion and for a good prognosis; therefore, the tooth has to be reimplanted immediately, so that its functions can be preserved.[10,11]

Orthodontic treatment in patients with traumatized teeth is not contraindicated; however, clinical and radiographic examination of the repair and/or complications after the traumatic injury should be performed before treatment.[12,13] Accordingly, the aim of the present study is to report a clinical case of an adult patient with generalized bone loss whose anterior teeth had been avulsed after a fall and reimplanted, with subsequent orthodontic tooth movement for Class II malocclusion correction.

DIAGNOSIS

Female patient, aged 49 years and 1 month, was referred by an implant dentist, who recommended malocclusion correction for later prosthetic rehabilitation of her missing posterior teeth and traumatized anterior teeth (Fig 1). The patient reported "*slipping in the shower about 10 months before, and feeling her anterior teeth falling right out of her mouth.*" The patient's general health status was good, but her oral health was poor, since the following tooth elements were missing: #17 (maxillary right second molar), #36 (mandibular left first molar), and #46 and #47 (mandibular right first and second molars). The patient had extensively restored teeth and anterior teeth with large gingival recession, with history of trauma followed by avulsion of teeth #11, #21, and #22 (maxillary central incisors and maxillary lateral incisor). A full orthodontic workup was requested prior to the treatment.

Figure 1: Initial extraoral and intraoral photographs.

Figure 2: Initial frontal view of the maxillary dental arch, showing splinted and extruded reimplanted incisors, in addition to extrusion of maxillary right first molar.

The clinical extraoral examination revealed slightly enlarged lower third of the face, lip incompetence at rest, and dental protrusion. The intraoral examination showed Class II division 1 malocclusion, deep overbite (5 mm), overjet (5 mm), coincident midlines, maxillary and mandibular crowding (discrepancies of -4.3 mm and -3 mm, respectively), mandibular molars inclined mesially, extruded maxillary right first molar (#16) with gingival recession, in addition to extruded and splinted maxillary incisors with gingival recession (Figs 1 and 2).

The radiographic examination revealed generalized bone loss, which was quite pronounced in maxillary incisors, maxillary right first molar (#16), and mandibular left second molar (#37). The anterior teeth with history of traumatic injury followed by avulsion (#11, #21, and #22) exhibited obturated root canals and largely restored crowns (Figs 3 and 4). There was also pronounced mesial inclination of mandibular left molars.

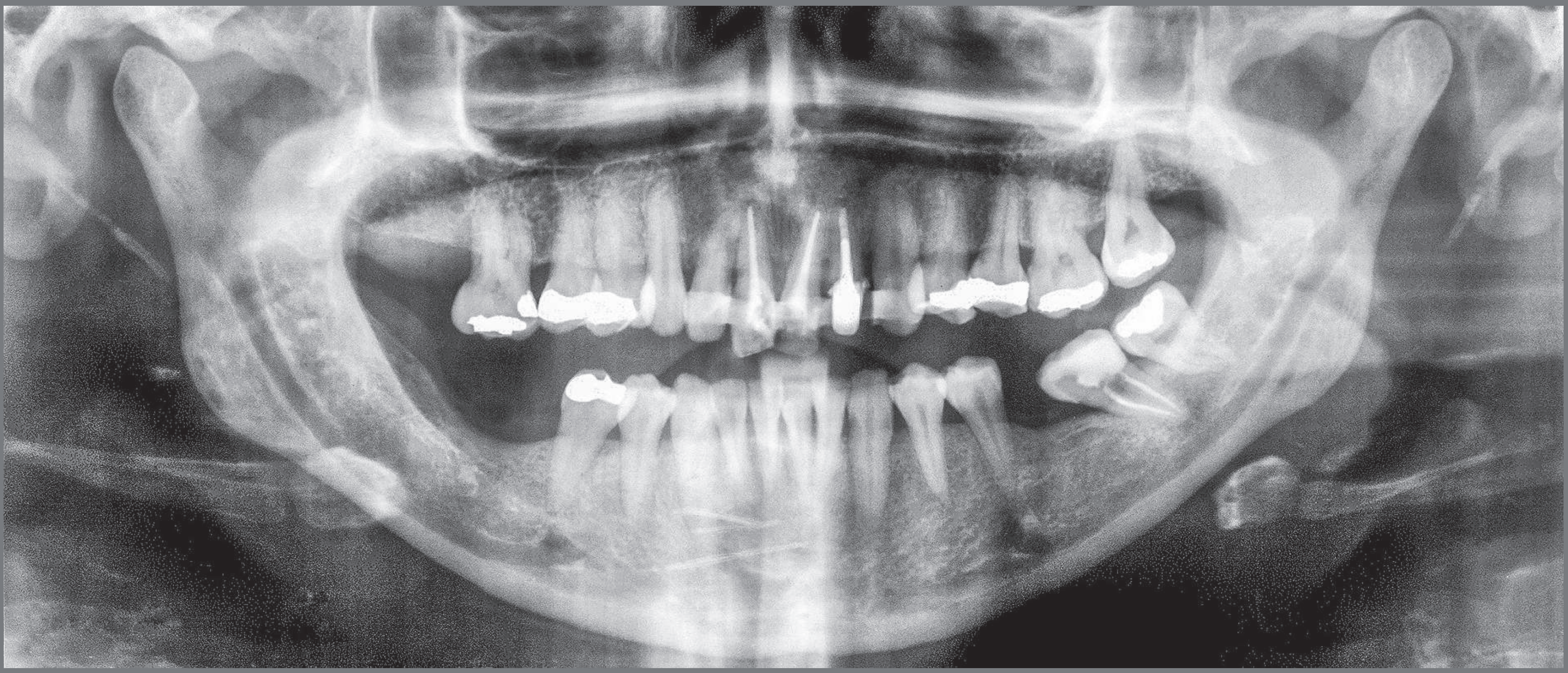

Figure 3: Initial panoramic radiograph.

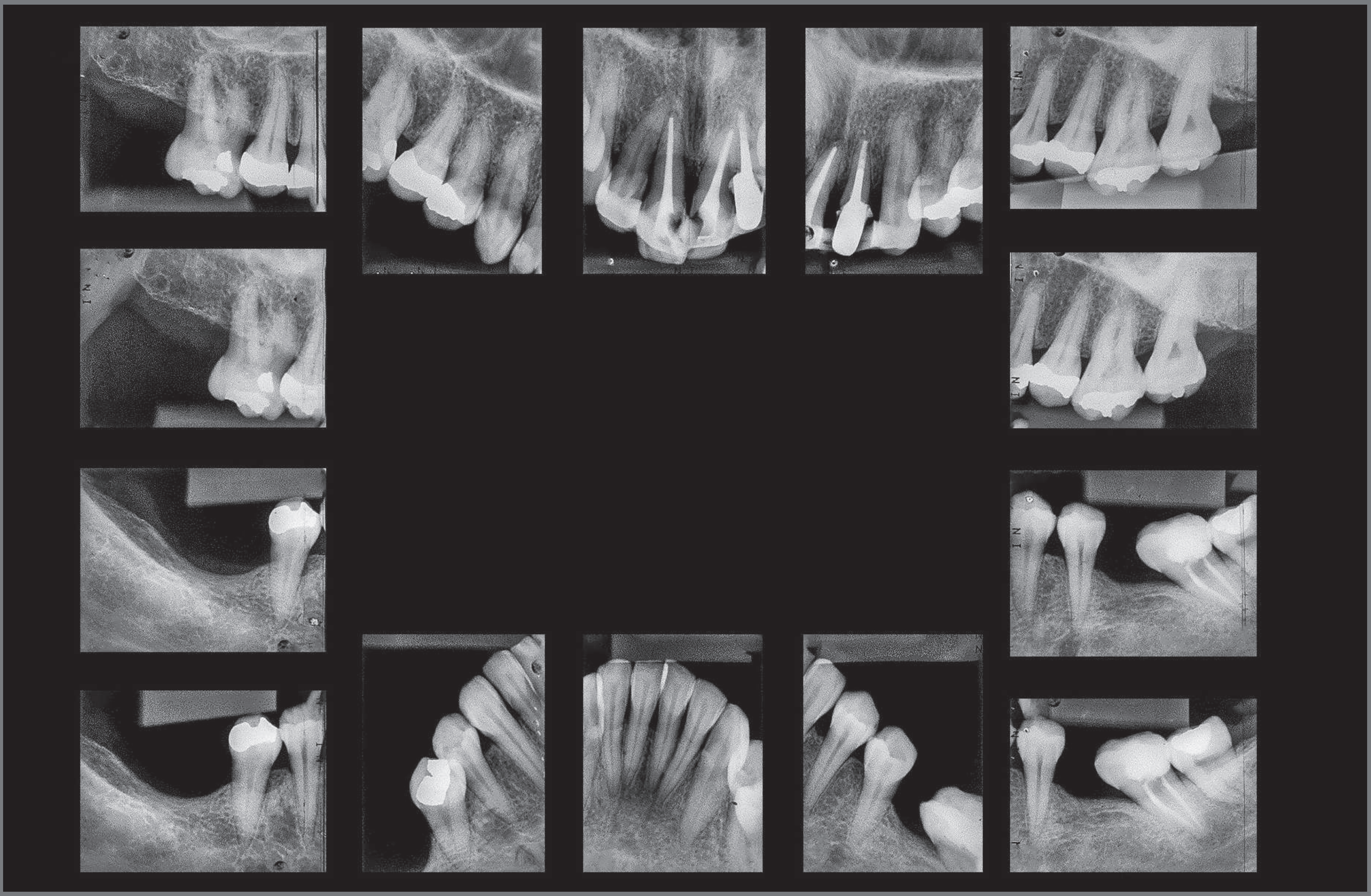

Figure 4: Initial periapical radiographs.

The cephalometric analysis revealed skeletal Class II malocclusion (ANB = 5°), high mandibular plane angle (SnGoGn = 42°), and prominent and buccally inclined maxillary and mandibular incisors (1.NA = 39°, 1-NA = 10 mm, 1.NB = 33°, and 1-NB = 8 mm). The cephalometric profile indicated protrusion, with UL-S = +3 mm and LL-S = +4 mm (Fig 5).

TREATMENT OBJECTIVES

The treatment objectives of the present clinical case were as follows: creation of space in dental arches for orthodontic tooth movement; bilateral Class II relationship correction; bimaxillary protrusion correction; uprighting of mandibular molars, opening space for dental implants; intrusion and distalization of maxillary right first molar (#16); and maintenance and intrusion of traumatized maxillary incisors.

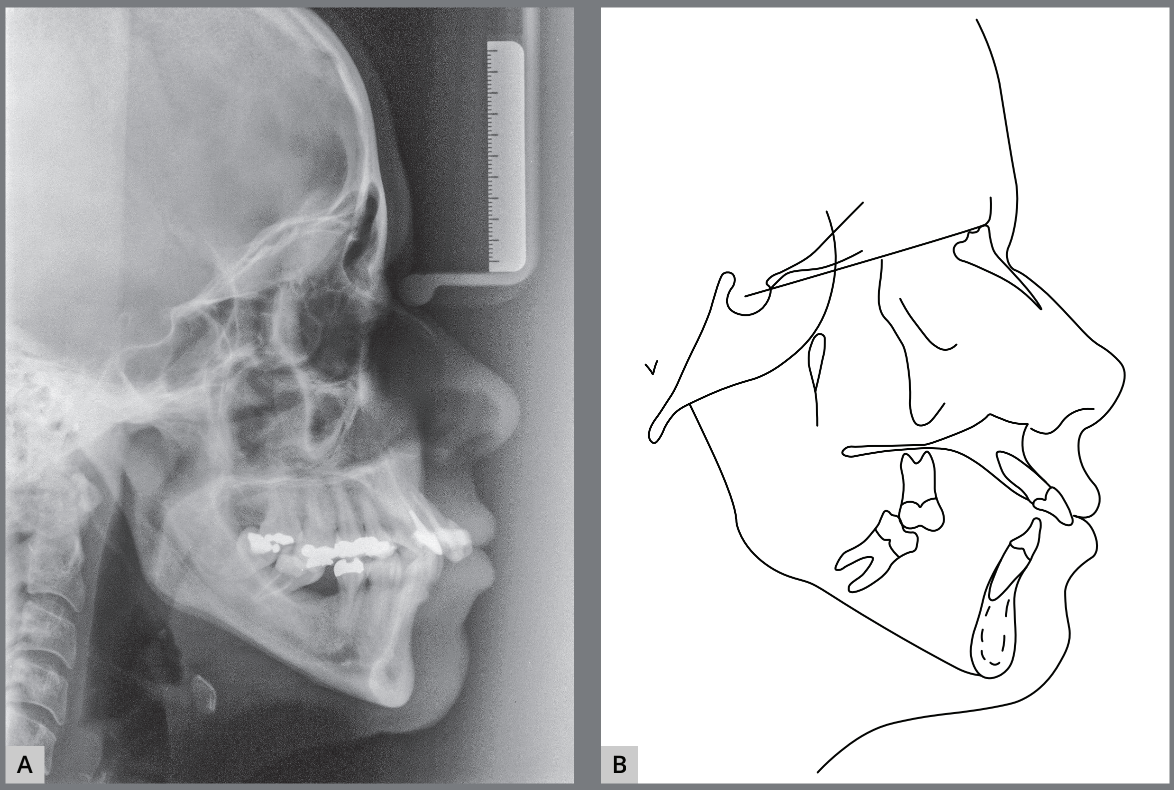

Figure 5: Initial cephalometric radiograph **(A)** and **(B)** cephalometric tracing.

TREATMENT OPTIONS

» Extraction of maxillary central incisors (#11 and #21) and of maxillary left lateral incisor (#22), followed by their replacement with osseointegrated implants, in addition to distalization of maxillary posterior teeth supported by orthodontic mini-implants.

» Extraction of maxillary central incisors (#11 and #21) and of maxillary left lateral incisor (#22), followed by mesialization of maxillary right lateral incisor (#12) towards the maxillary right central incisor (#11), as well as mesialization of maxillary right canine (#13) towards the lateral incisor. Placement of osseointegrated implants, with replacement of maxillary central incisor and reshaping of anterior teeth.

» Conservative treatment with intrusion of maxillary central and lateral incisors, combined with Class II malocclusion correction with mini-implant-supported distalization of posterior teeth.

TREATMENT PROGRESS

A conservative orthodontic treatment was proposed. Initially, the appliance was mounted with the Edgewise standard (0.022 x 0.030-in slot) continuous technique in the lower arch and segmented technique in the upper arch (Fig 6). Segmentation in the upper arch was aimed at aligning the maxillary posterior teeth, to allow future distalization with mini-implant-supported sliding jigs. Maxillary and mandibular alignment was made with 0.014-in, 0.016-in, and 0.018-in stainless steel archwires. After this, 0.020-in continuous archwires were placed for relief in the maxillary anterior region (Fig 7), whereas a 0.018 x 0.025-in archwire was placed in the lower arch.

After placement of the 0.020-in maxillary archwire, bilateral orthodontic mini-implants were inserted and used as support for the sliding jigs, for maxillary molar distalization. The mini-implant on the right side was positioned in the tuber region to create a resultant movement of intrusive and distalizing forces exerted on the maxillary first molar, which was extruded and mesially inclined. Premolar distalization was then obtained. A hook supported by a Gurin lock with an open coil spring on the right side and elastic chains on the left side was used (the sliding jig anchored the molars on the left side so that they would not move mesially during the insertion of the elastic chain between the molars and premolars) (Figs 8, 9 and 10).

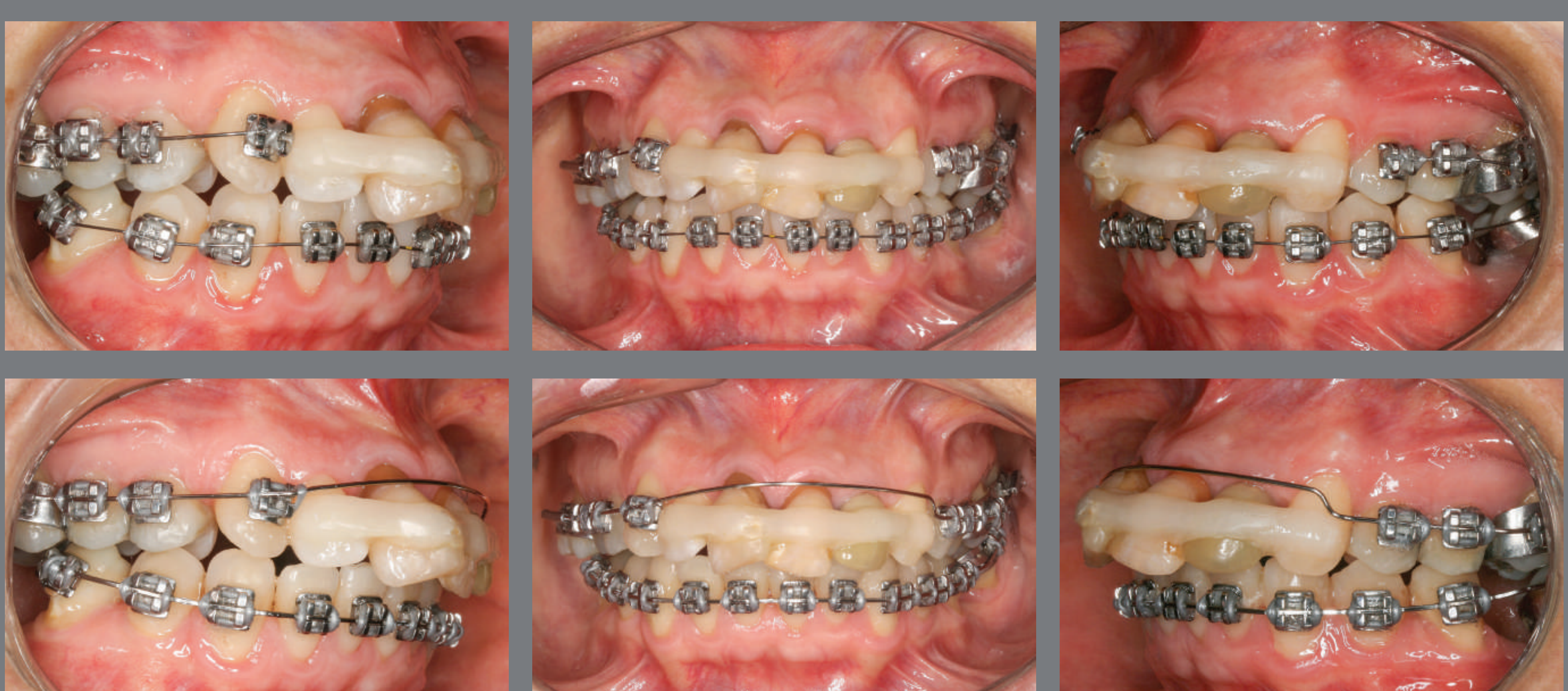

Figure 6: Tooth alignment and leveling at baseline. Maxillary archwire with anterior relief.

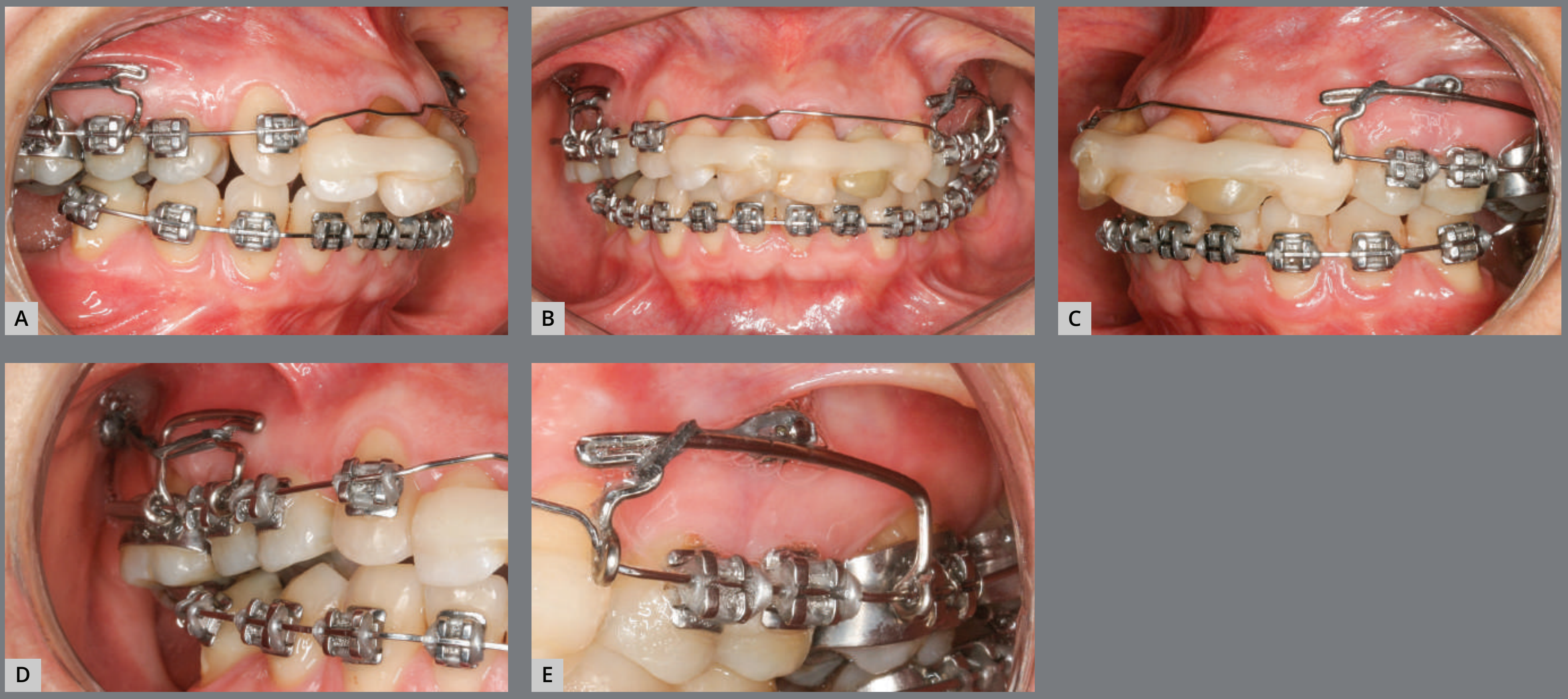

Figure 7: A-C) Initial distalization of maxillary teeth supported by mini-implants. **D-E)** Close-up views of the distalization system, consisting of sliding jig and mini-implant.

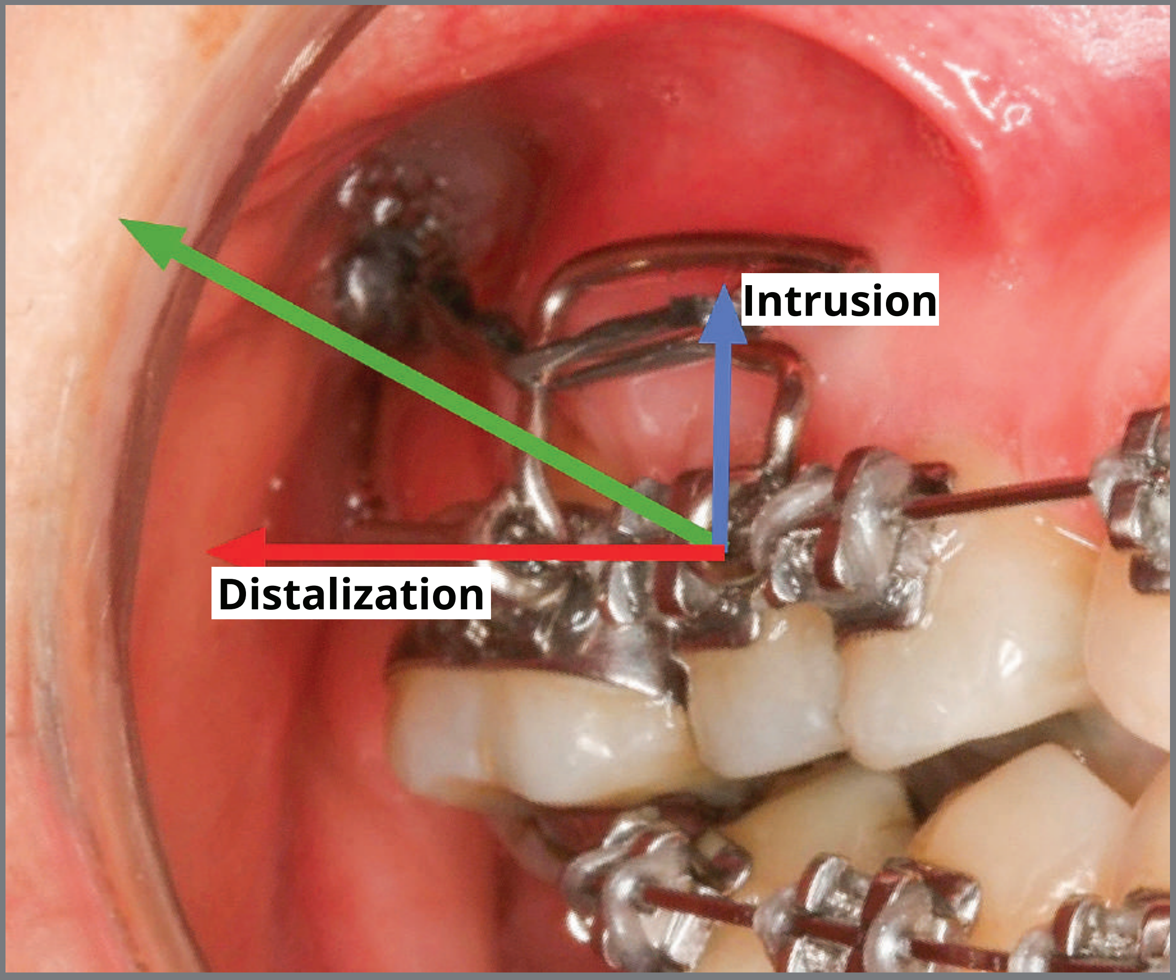

Figure 8: Distalization and intrusion of maxillary right first molar.

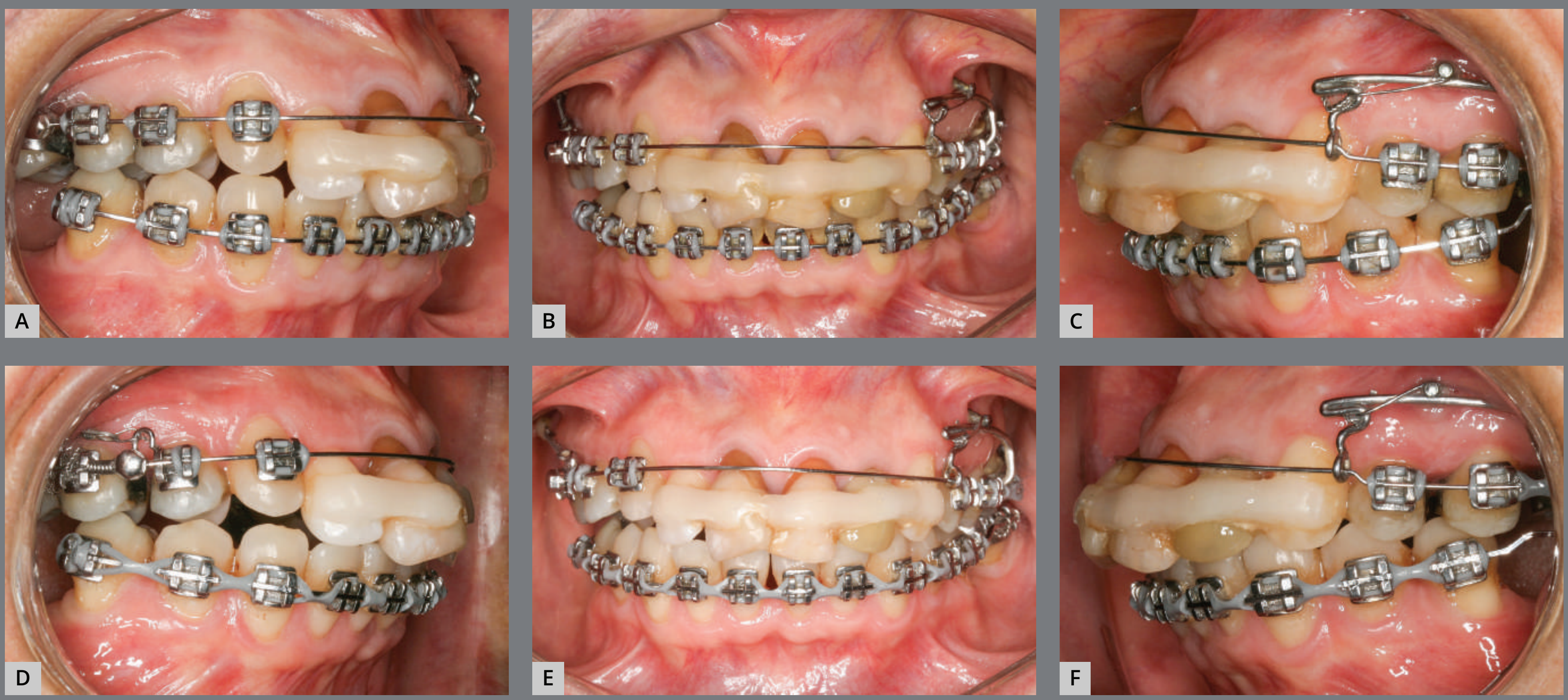

Figure 9: A-C) Molar distalization. **D-F)** Premolar distalization.

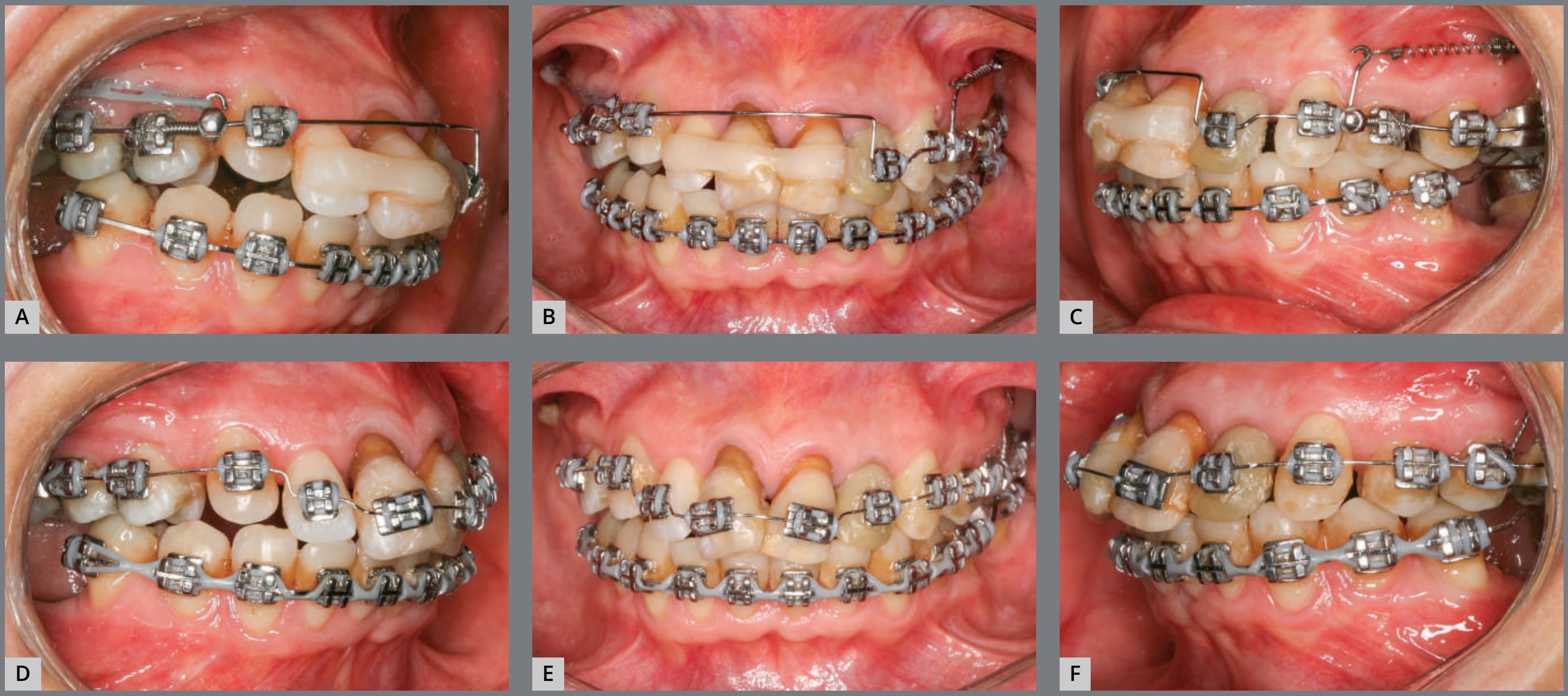

Figure 10: A-C) Premolar distalization with replacement of sliding jigs with archwire-supported hooks, with inclusion of tooth #22. **D-F)** Removal of splint, bonding of anterior teeth, and initial alignment and leveling.

After creating a space in the maxillary left anterior region, the left lateral incisor (#22) was released from the splint and the orthodontic bracket was bonded. At this stage, another 0.020-in passive archwire was bent in this region and tooth #22 was included (Fig 11). This tooth had moderate mobility (grade 2). The splint was removed after 60 days and tooth movement was then checked. This stage of treatment caused a lot of concern, since the teeth had greater mobility. A 0.016-in passive archwire was chosen, since an active archwire could pull the teeth out. In subsequent visits, the archwire was adjusted as the teeth were aligned and leveled. After adjustment of the archwire and alignment and leveling of teeth, mobility was reduced. Because of that, 0.018-in, 0.020-in, 0.017 x 0.025-in, and 0.019 x 0.025-in archwires were used for tooth alignment and leveling. A step-up bend was used in the 0.019 x 0.025-in archwire, for intrusion of the extruded anterior teeth (Figs 12 and 13).

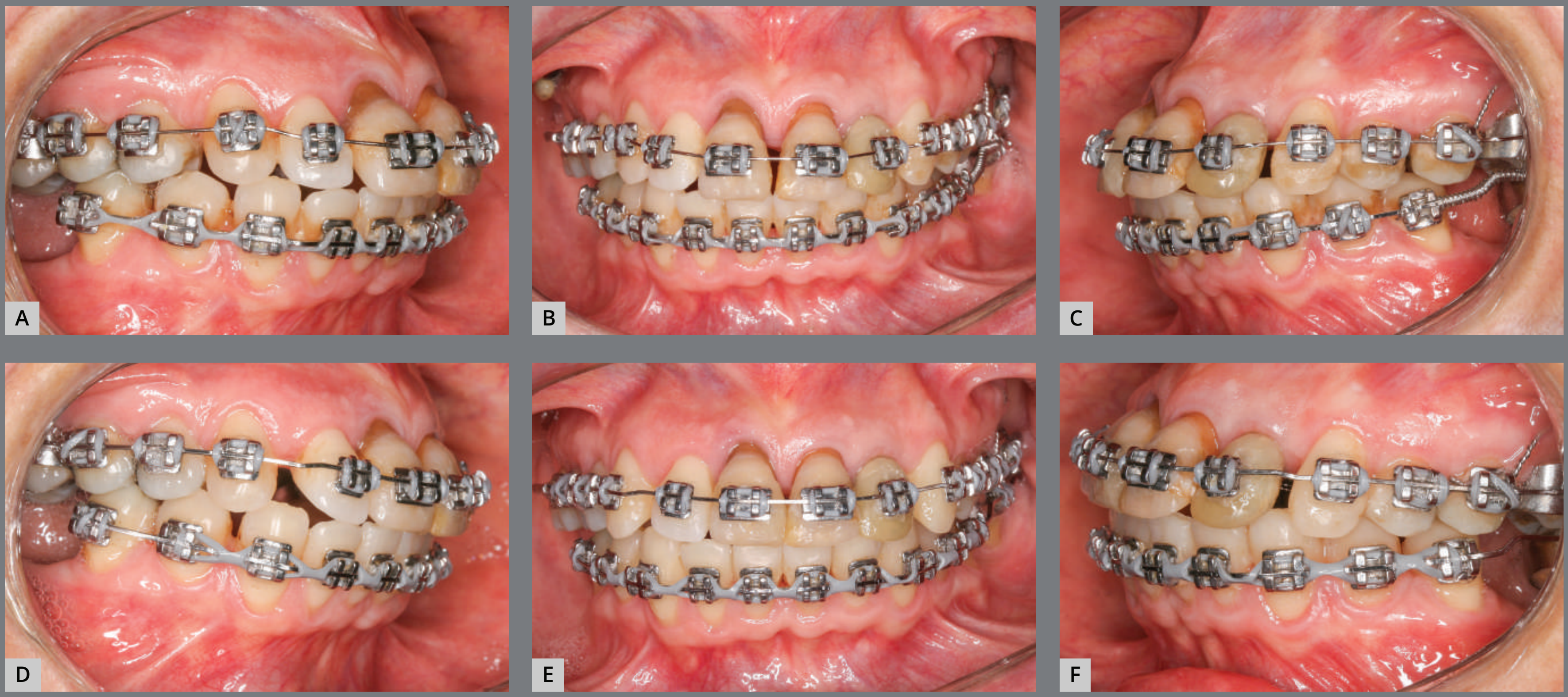

Figure 11: Anterior teeth in alignment and leveling stage.

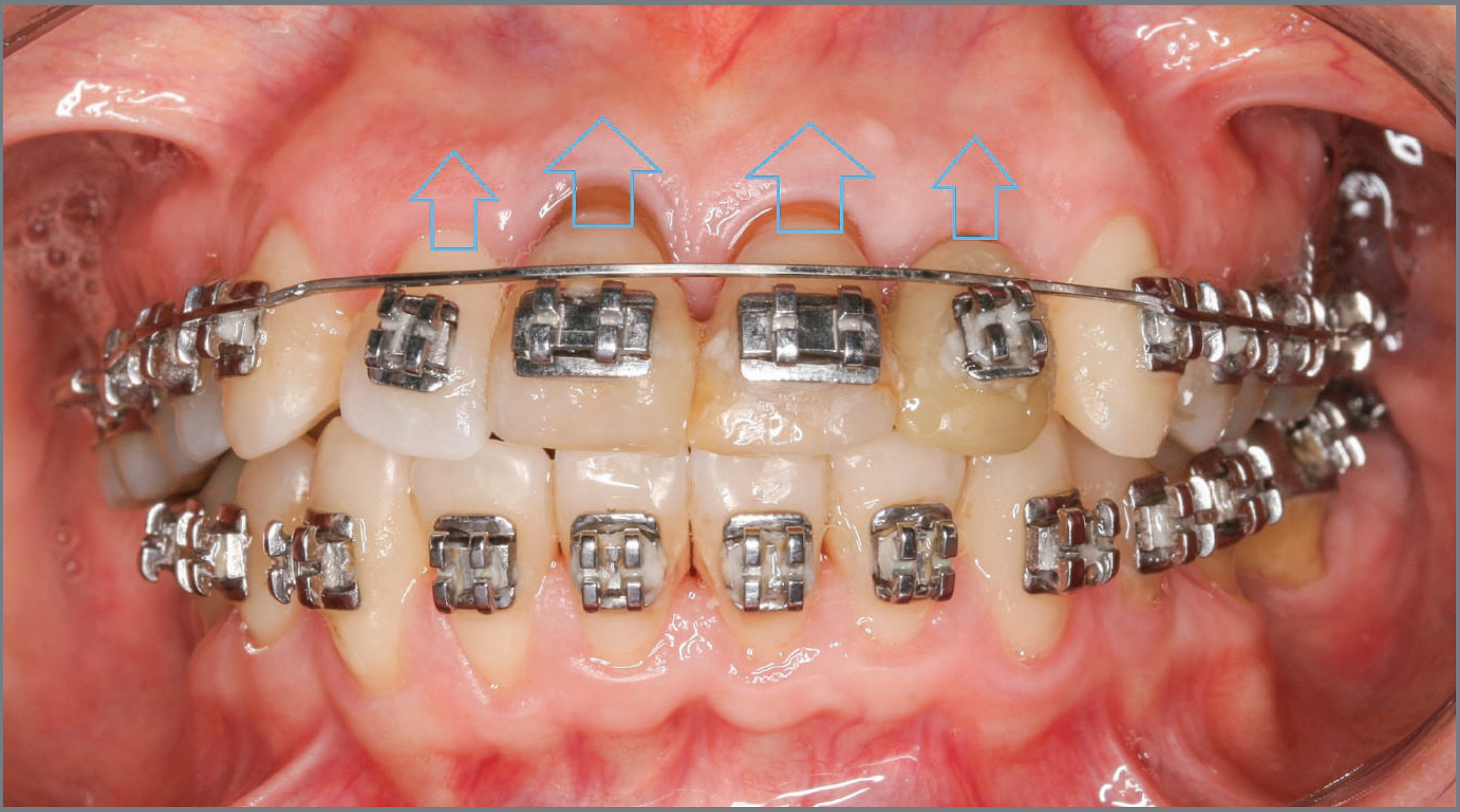

Figure 12: Activation of maxillary archwire, for intrusion of maxillary anterior teeth.

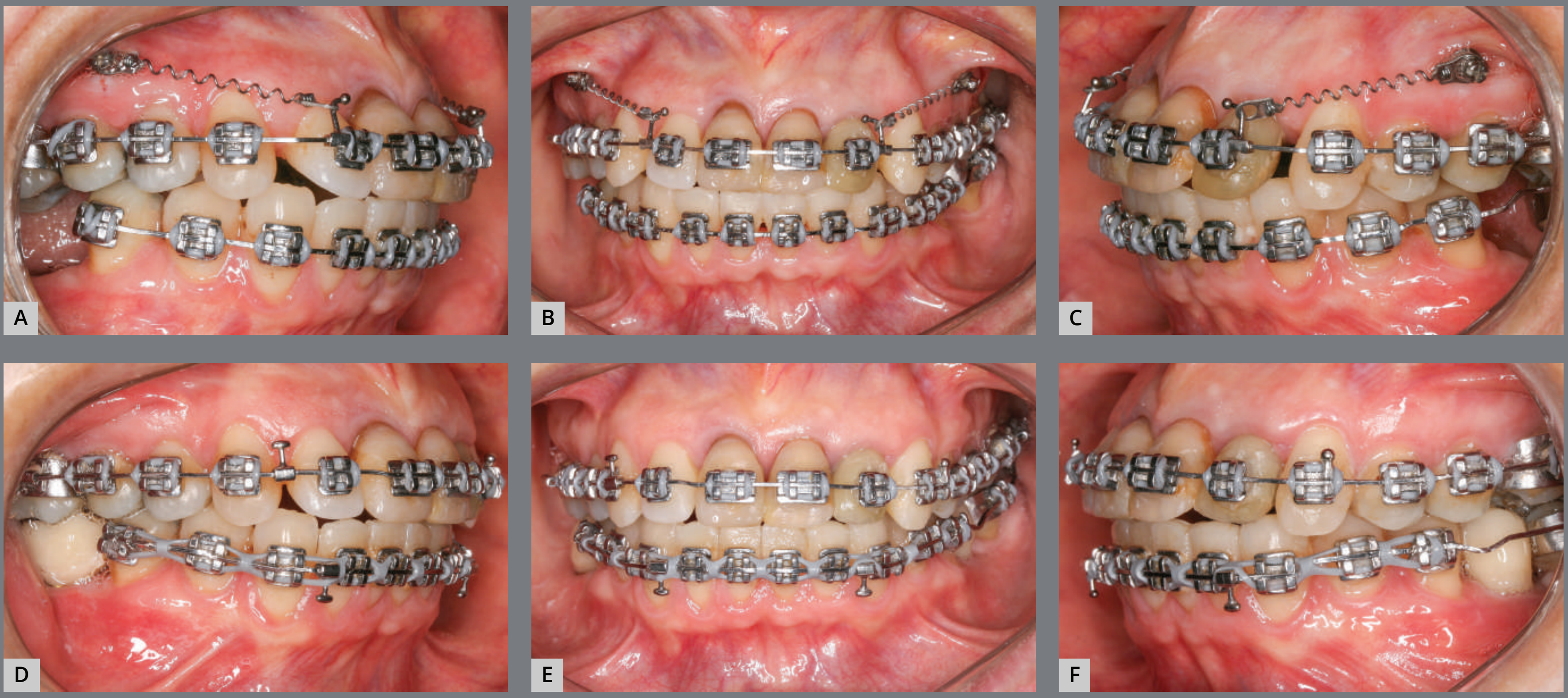

Figure 13: A-C) Placement of maxillary mini-implants, used for closure of maxillary spaces and intrusion of maxillary anterior teeth. **D-F)** Maxillary arch with closed spaces.

Meanwhile, in the lower dental arch, spaces were closed, tooth alignment and leveling were carefully adjusted, and the mesially inclined molars were uprighted.

Thereafter, mini-implants were placed between maxillary premolars ##14/15 and #24/25, which served as support for closure of maxillary spaces, with posterior and maxillary repositioning (Fig 14). Note that, from the beginning of alignment and leveling, the anterior teeth became more intruded, improving their relationship with the other teeth and with the bone base (Fig 15).

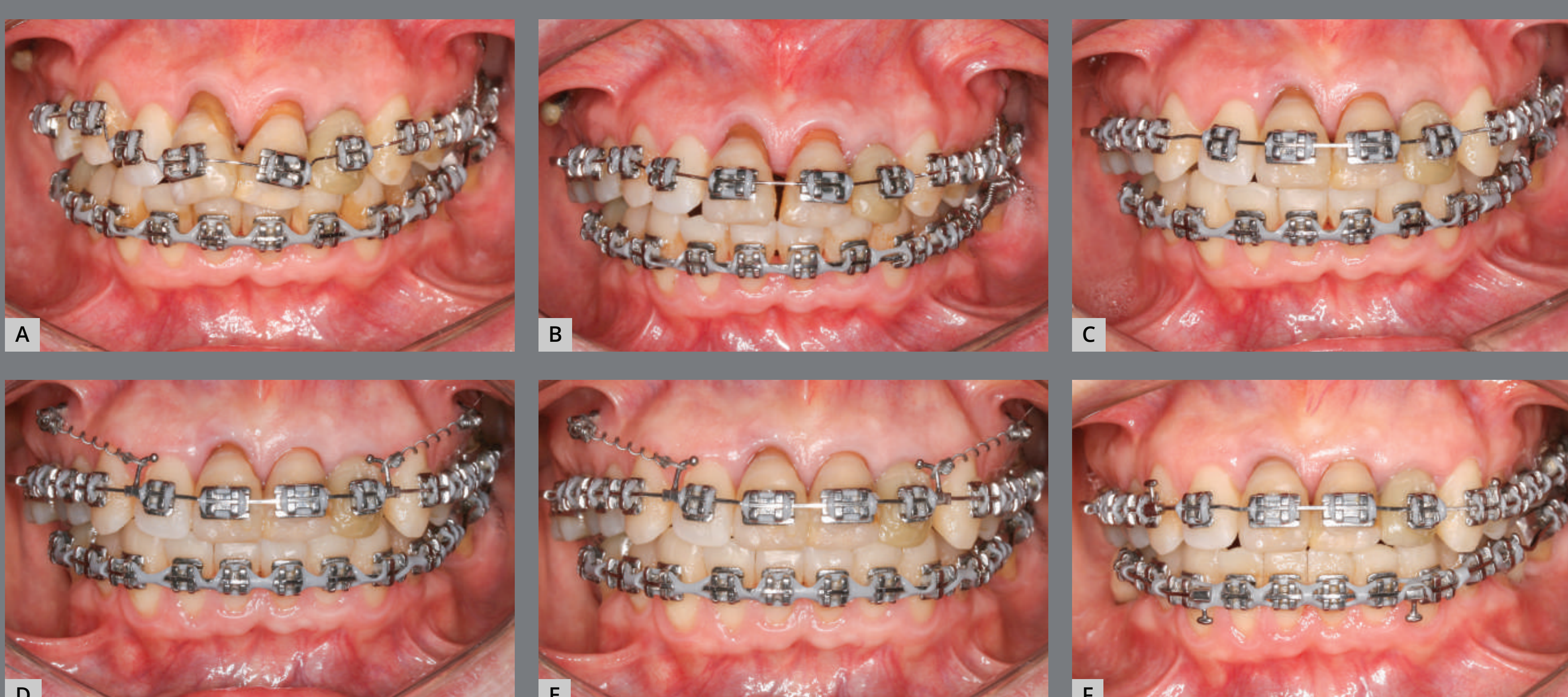

Figure 14: Frontal views during maxillary anterior teeth alignment and leveling associated with intrusion: **A)** Initial alignment and leveling; **B)** at 60 days; **C)** at 120 days, **D)** at 180 days; **E)** at 210 days, and **E)** at 270 days after the initial alignment.

Figure 15: Extraoral and intraoral photographs at the end of treatment.

After 36 months of treatment, the orthodontic appliance was removed, with subsequent placement of a 3x3 intercanine retainer. A wraparound retainer was used in the maxillary dental arch, in association with a fixed retainer between the maxillary central incisors and the maxillary right lateral incisor (#12 and #21) (Fig 15).

The patient was referred to a prosthetist for replacement of provisional prostheses on anterior teeth by definitive ones, in addition to periodontal follow-up. The prosthesis on the anterior teeth kept them together despite of extensive bone loss.

TREATMENT RESULTS

At the end of the orthodontic treatment, there was enough space for accommodation of teeth, good intercuspation, with overbite and bilateral Class II malocclusion correction. The mandibular molars were uprighted, creating space for the placement of osseointegrated implants. Esthetically, smile harmony and positioning of the teeth were enhanced (Fig 15). The anterior teeth were intruded, substantially improving mobility, which went from grade 3, in central incisors and right lateral incisor, to grade 1 (Figs 16 and 17).

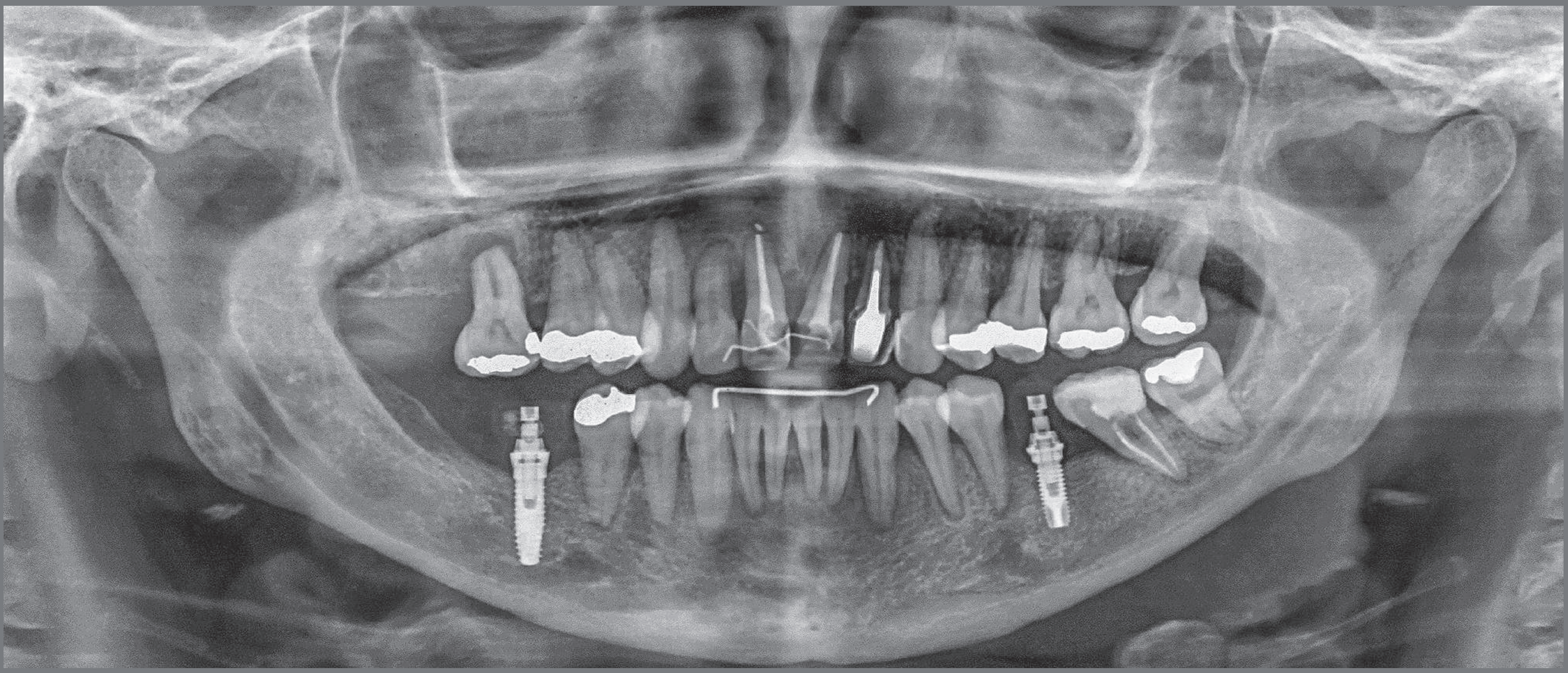

Figure 16: Panoramic radiograph at the end of treatment.

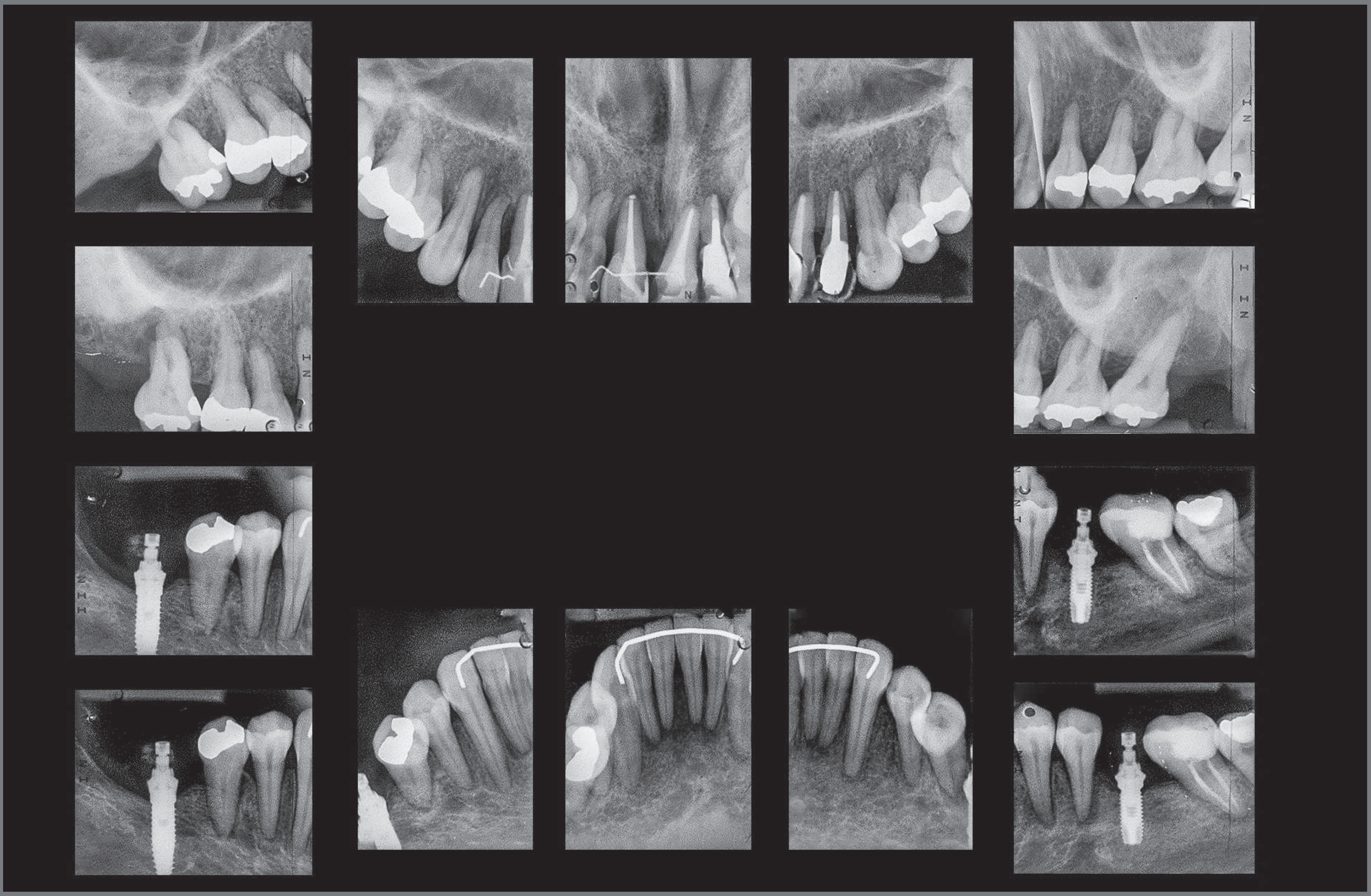

Figure 17: Periapical radiographs at the end of treatment.

Radiographically, it was verified the intrusion of the maxillary right first molar and of the maxillary anterior teeth, leading to better insertion of incisors into the bone bases (Figs 16, 17, 18 and 19). The lateral view shows that lip protrusion was corrected, improving positioning of the teeth. The mandibular plane remained stable.

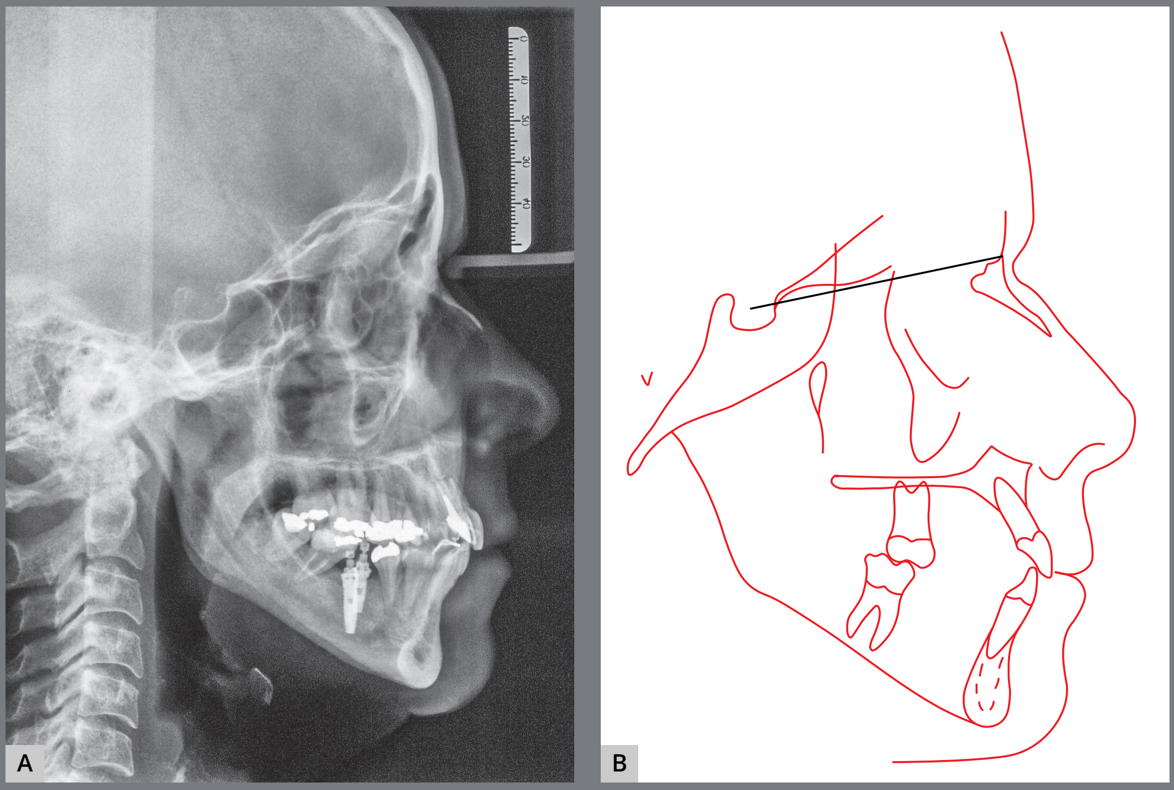

Figure 18: Cephalometric radiograph **(A)** and cephalometric tracing at the end of treatment **(B)**.

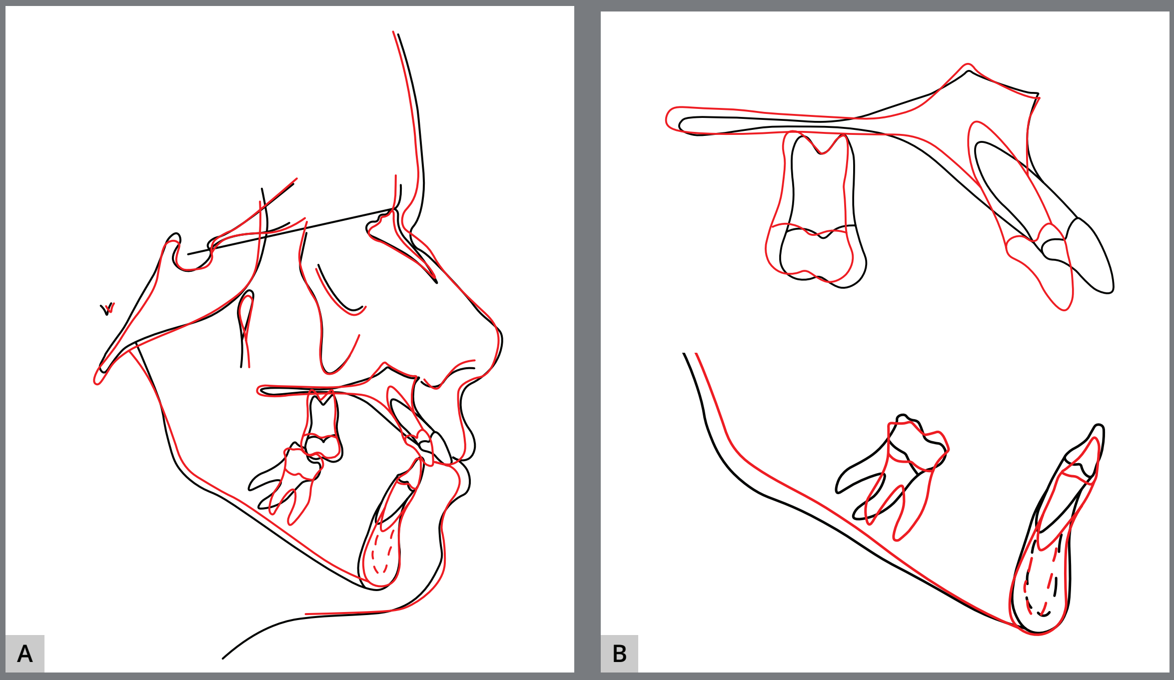

Figure 19: Total **(A)** and partial **(B)** superimpositions of the initial (black) and final (red) cephalometric tracings.

Figure 20: Extraoral and intraoral photographs 8 years after the end of treatment.

According to the cephalometric analysis, central and lateral incisors were repositioned, showing better insertion in bone bases at the end of the treatment. There was a change in point A after repositioning of the incisors, with consequent skeletal Class II malocclusion correction (Figs 18 and 19).

Eight years after removal of the fixed orthodontic appliance, the improvements achieved with its use were maintained (Fig 20), as it can be analyzed in the photographic and radiographic records (Figs 20 to 24 and Table 1).

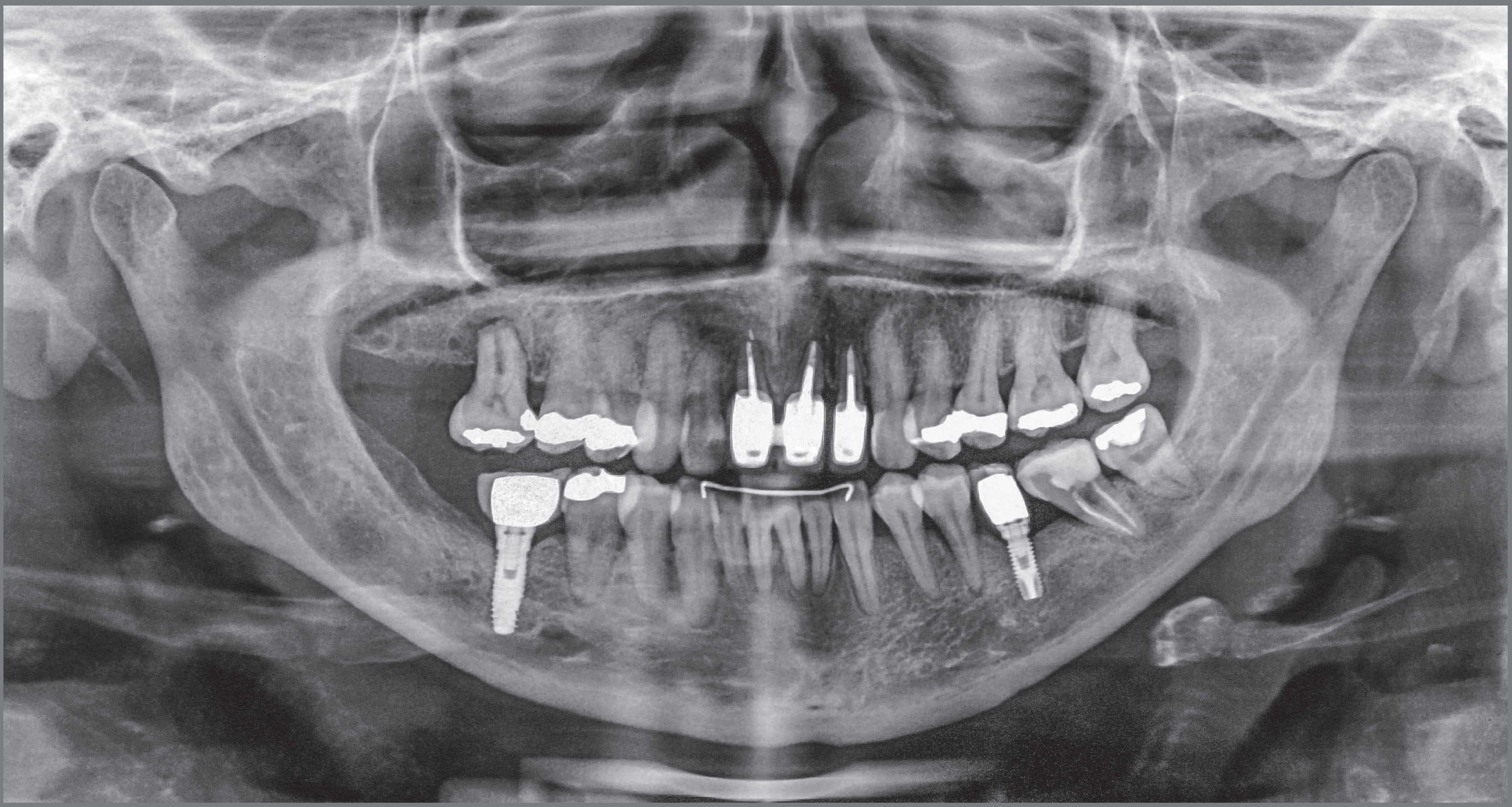

Figure 21: Panoramic radiograph 8 years after the end of treatment.

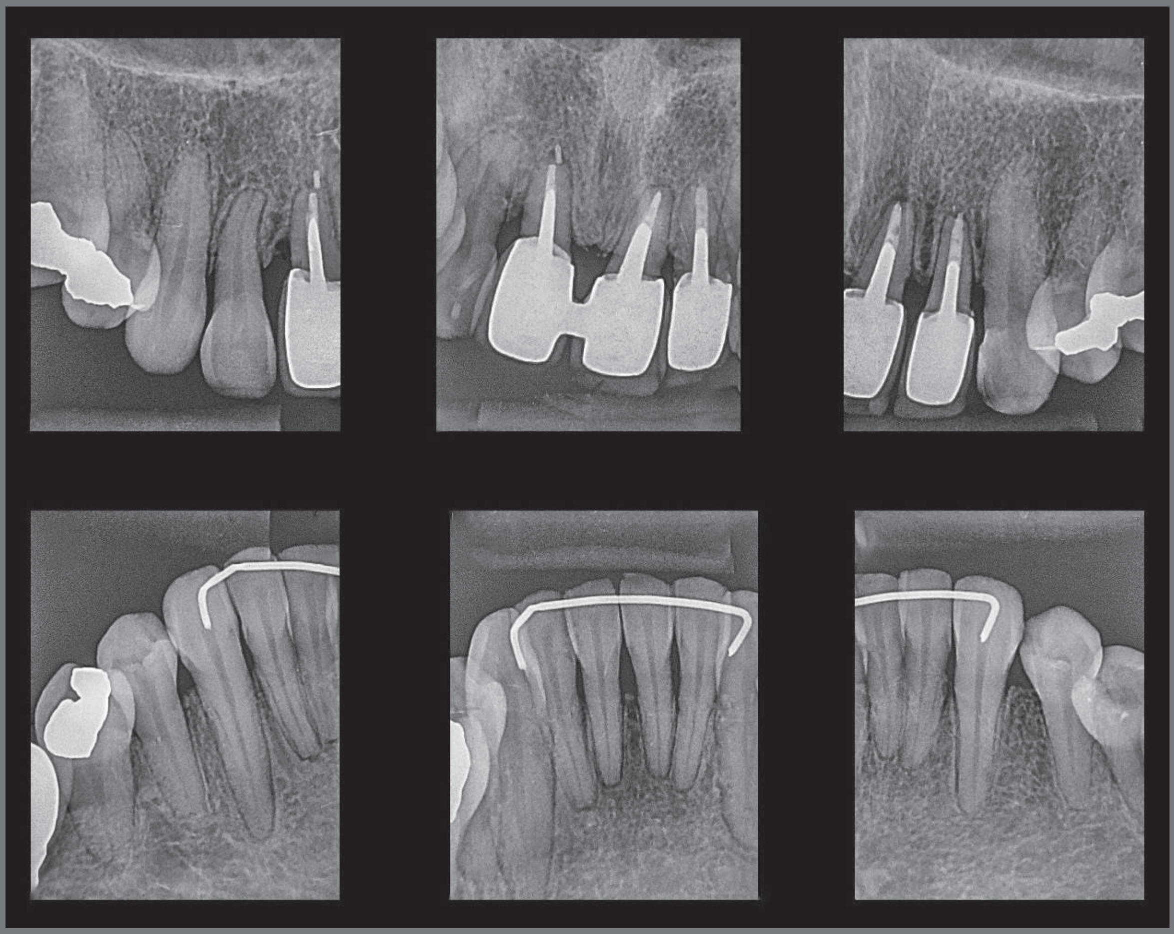

Figure 22: Periapical radiographs 8 years after the end of treatment.

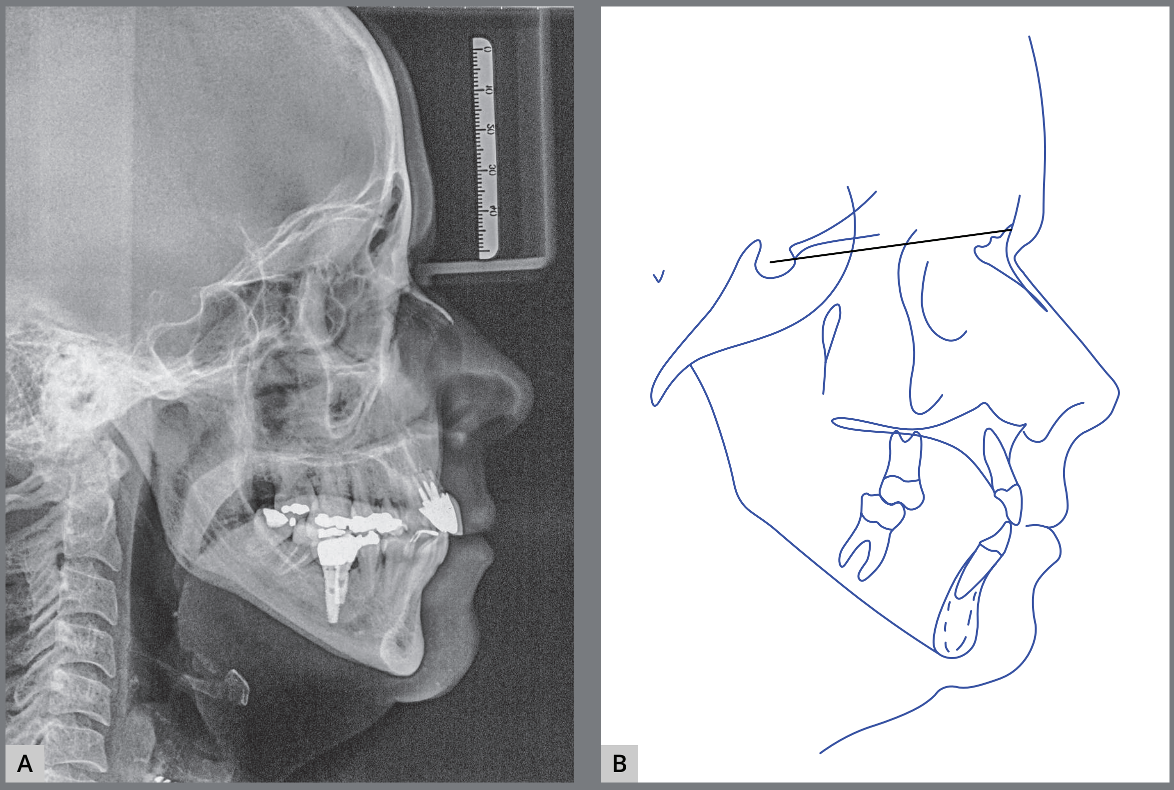

Figure 23: Cephalometric radiograph **(A)** and cephalometric tracing **(B)** 8 years after the end of treatment.

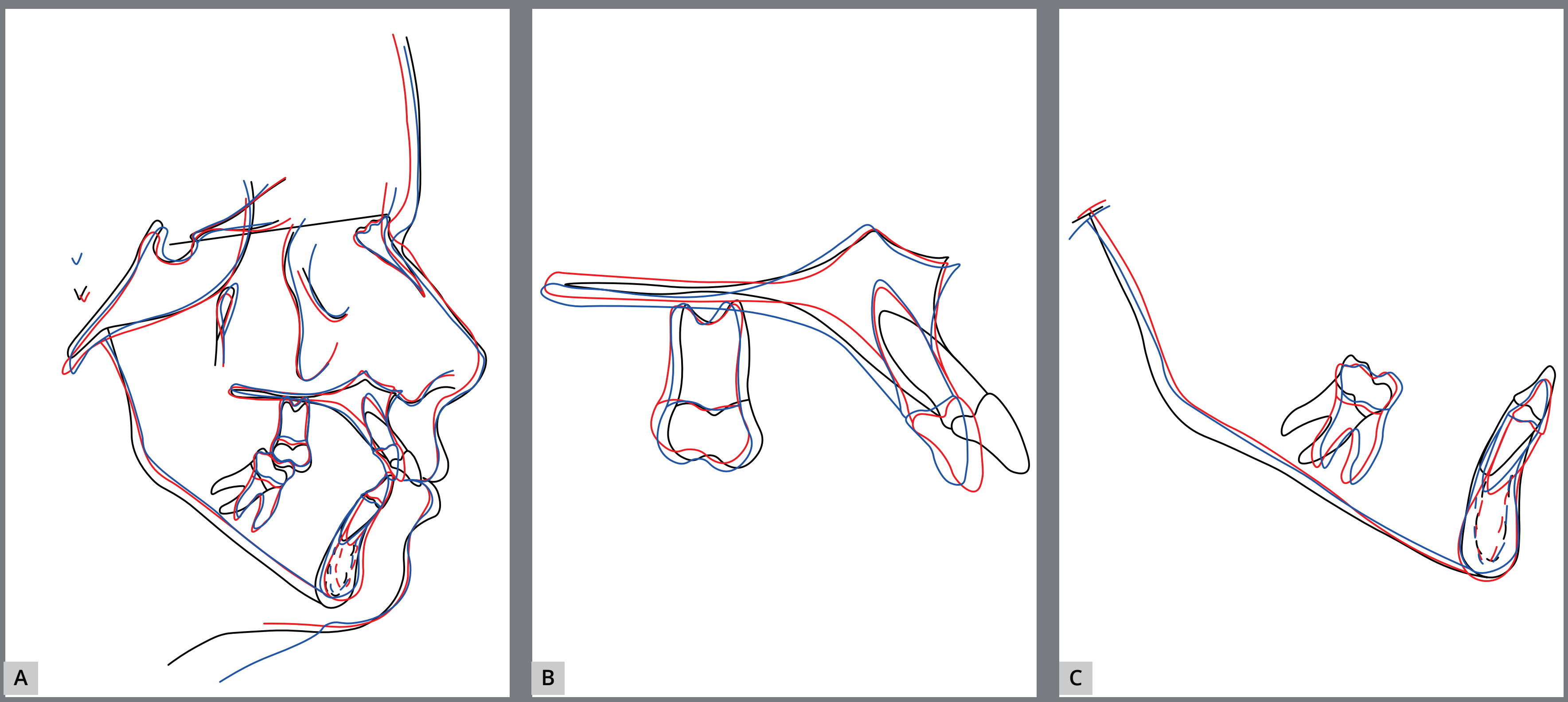

Figure 24: Total (**A**) and partial (B-**C**) superimpositions of cephalometric tracings: initial (black), final (red) and 8 years after the end of treatment (blue).

Table 1: Initial (A), final (B) and 8-year follow-up (C) cephalometric values.

	MEASURES		Normal	A	B	Diff. A/B	C
Skeletal pattern	SNA	(Steiner)	82°	83°	84°	1	84°
	SNB	(Steiner)	80°	78°	80°	2	80°
	ANB	(Steiner)	2°	5°	4°	1	4°
	Angle of convexity	(Downs)	0°	9°	9°	0	9°
	Y-axis	(Downs)	59°	59°	58°	1	57°
	Facial Angle	(Downs)	87°	90°	91°	1	91°
	SN.GoGn	(Steiner)	32°	42°	42°	0	42°
	FMA	(Tweed)	25°	32°	28°	4	27°
Dental pattern	IMPA	(Tweed)	90°	93°	85°	8	87°
	1.NA (degrees)	(Steiner)	22°	39°	24°	15	17°
	1-NA (mm)	(Steiner)	4 mm	10mm	5mm	5	3mm
	1.NB (degrees)	(Steiner)	25°	33°	27°	6	28°
	1-NB (mm)	(Steiner)	4mm	8	7°	1	6°
	$\frac{1}{1}$ - Interincisal angle	(Downs)	130°	103°	125°	22	128°
	1 - APg	(Ricketts)	1mm	9mm	7mm	2	7mm
Profile	Upper Lip - Line S	(Steiner)	0	3	0	3	-0.5
	Lower Lip - Line S	(Steiner)	0	4	0	4	0

DISCUSSION

The aim of the present study was to describe the conservative orthodontic treatment of a patient with Class II malocclusion whose anterior teeth had been reimplanted after their avulsion during a fall. The traumatic injury to the teeth might have been due to pronounced overjet (5 mm at baseline). According to Nguyen et al,[14] individuals with an overjet greater than 3 mm have twice the risk for injury to their anterior teeth than those with an overjet of less than 3 mm.

Dental avulsion is characterized by total detachment of the tooth from its socket and accounts for approximately 0.5% to 16% of dentoalveolar injuries to permanent teeth.[15] The time between avulsion and reimplantation, as well as where the tooth was kept during this period, are crucial for the prognosis, which is oftentimes poor.

The patient described in this study reported that her teeth had been knocked out of her mouth and fallen to the floor after she had slipped in the shower. She also reported being unconscious for about 5 minutes and receiving first aid from a public emergency service before being taken to hospital, where a dentist reimplanted her teeth. On the way to the hospital, her teeth were kept in physiological saline, which is considered as the best transport medium.[16] The time between the traumatic injury and tooth reimplantation was shorter than 1 hour, and her teeth was maintained in physiological saline throughout. As recommended by Donaldson and Kinirons,[17] the teeth should not be allowed to become dry for longer than 15 minutes. Proper storage within a short period of time might have favored the good prognosis of her teeth.

Prior to the treatment, the patient had been referred to a periodontist for having her periodontal status checked and necessary procedures performed before orthodontic tooth movement. Note that if active gingival inflammation is controlled, intrusion can be a reliable therapeutic treatment in patients with reduced periodontal support, because it does not result in a decrease of the marginal bone level.[18,19] For optimum results, intrusion should be performed with light forces, and the line of action of the force should pass close to the center of resistance.[20] Light forces were used during intrusion. As mentioned earlier, alignment and leveling were performed with a passive stainless steel archwire, which was progressively adjusted as the teeth responded to orthodontic movement. After full alignment, orthodontic mini-implants were placed and used as support for space closure and intrusion. The mini-implants were placed between the premolars in a position that allowed the line of action of the force to be inclined upward, with anterior distalization and intrusion. The same rationale was applied for distalization and intrusion of the maxillary right first molar. In this case, the mini-implant was placed in the tuber, allowing the line of action of the force between the sliding jig and the mini-implant, to favor distalization and intrusion. Ahn et al.[21] used a system with the same principle for the distalization and intrusion of protruded and extruded anterior teeth with periodontal loss.

Before treatment, gingival recession of the anterior teeth was 2 mm, but it increased substantially during orthodontic treatment. Presumably, this occurred because of continuous extrusion of maxillary anterior teeth as an attempt to establish contact with the mandibular ones, and also because of the pronounced protrusion of those teeth.

Cardaropoli et al.[18] evaluated the role of orthodontic intrusion in the reduction of gingival recession and probing depth around maxillary incisors of adult periodontal patients and found that the mean reductions in gingival recession were 0.96 and 1.71 mm at the buccal and mesial sites, respectively. In the present case, the reduction was more remarkable, as it was 5.5 mm at the beginning of intrusion of anterior teeth.

Nevins and Wise[22] concluded that orthodontically moving teeth into infrabony defects might modify the defect's morphology, reduce probing depth, and resolve the bony defect. This finding was described by Pithon[23] for orthodontic movement of anterior teeth with extensive bone loss and also in the present clinical case. Better insertion was clinically evident, since in the new position the teeth showed lower mobility than at the beginning of orthodontic movement.

CONCLUSIONS

The option of orthodontic treatment with a conservative approach can be a very favorable treatment alternative in malocclusions associated with trauma followed by avulsion of anterior teeth that are reimplanted after a short time.

AUTHOR'S CONTRIBUTION

Matheus Melo Pithon (MMP): *Conception or design of the study; Writing the article; Critical revision of the article; Final approval of the article; Overall responsibility:* MMP.

Patient displayed in this article previously approved the use of their facial and intraoral photographs.

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REFERENCES

1. Wong L, Ryan FS, Christensen LR, Cunningham SJ. Factors influencing satisfaction with the process of orthodontic treatment in adult patients. Am J Orthod Dentofacial Orthop. 2018 Mar;153(3):362-70.
2. Li SN, Zhang D. Recent progress of adult orthodontic treatment. Zhongguo Yi Xue Ke Xue Yuan Xue Bao. 2014 Dec;36(6):675-9.

3. Oliveira PG, Tavares RR, Freitas JC. Assessment of motivation, expectations and satisfaction of adult patients submitted to orthodontic treatment. Dental Press J Orthod. 2013 Mar-Apr;18(2):81-7.

4. Melo AC, Carneiro LO, Pontes LF, Cecim RL, Mattos JN, Normando D. Factors related to orthodontic treatment time in adult patients. Dental Press J Orthod. 2013 Sep-Oct;18(5):59-63.

5. Melo MMC, Cardoso MG, Faber J, Sobral A. Risk factors for periodontal changes in adult patients with banded second molars during orthodontic treatment. Angle Orthod. 2012 Mar;82(2):224-8.

6. Sabatoski CV, Bueno RC, Reyes Pacheco AA, Pithon MM, Tanaka OM. Combined periodontal, orthodontic, and prosthetic treatment in an adult patient. Case Rep Dent. 2015;2015:716462.

7. Zuhal K, Semra OE, Huseyin K. Traumatic injuries of the permanent incisors in children in southern Turkey: a retrospective study. Dent Traumatol. 2005 Feb;21(1):20-5.

8. Zafar K, Ghafoor R, Khan FR, Hameed MH. Awareness of dentists regarding immediate management of dental avulsion: knowledge, attitude, and practice study. JPMA Pakistan Med Assoc. 2018 Apr;68(4):595-9.

9. Antov HK. Simple techniques for managing dental avulsion in the GP setting. Br J Gen Pract. 2019 Feb;69(679):66.

10. Castilho LR, Sundefeld ML, Andrade DF, Panzarini SR, Poi WR. Evaluation of sixth grade primary schoolchildren's knowledge about avulsion and dental reimplantation. Dent Traumatol. 2009 Aug;25(4):429-32.

11. Nuzzolese E, Cirulli N, Lepore MM, D'Amore A. Intentional dental reimplantation: a case report. J Contemp Dent Pract. 2004 Aug 15;5(3):121-30.

12. Andersson L, Andreasen JO, Day P, Heithersay G, Trope M, DiAngelis AJ, et al. Guidelines for the management of traumatic dental injuries. II. Avulsion of permanent teeth. Pediatr Dent. 2017 Sep 15;39(6):412-9.

13. Oluwatosin SO, Folakemi OA, Edamisan TO. Orthodontic management of traumatic avulsion of permanent incisors in a child with sickle cell anaemia: a case report. Cases J. 2009 Aug 26;2:8123.

14. Nguyen QV, Bezemer PD, Habets L, Prahl-Andersen B. A systematic review of the relationship between overjet size and traumatic dental injuries. Eur J Orthod. 1999 Oct;21(5):503-15.

15. Diangelis AJ, Andreasen JO, Ebeleseder KA, Kenny DJ, Trope M, Sigurdsson A, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries. II. Avulsion of permanent teeth. [Hebrew edition]. Refu'at ha-peh veha-shinayim (1993). 2014 Apr;31(2):57-68, 90.

16. Souza BD, Bortoluzzi EA, Silveira Teixeira C, Felippe WT, Simoes CM, Felippe MC. Effect of HBSS storage time on human periodontal ligament fibroblast viability. Dent Traumatol. 2010 Dec;26(6):481-3.

17. Donaldson M, Kinirons MJ. Factors affecting the time of onset of resorption in avulsed and replanted incisor teeth in children. Dent Traumatol. 2001 Oct;17(5):205-9.
18. Cardaropoli D, Re S, Corrente G, Abundo R. Intrusion of migrated incisors with infrabony defects in adult periodontal patients. Am J Orthod Dentofacial Orthop. 2001 Dec;120(6):671-5.
19. Melsen B, Agerbaek N, Markenstam G. Intrusion of incisors in adult patients with marginal bone loss. Am J Orthod Dentofacial Orthop. 1989 Sep;96(3):232-41.
20. Agarwal S, Gupta S, Chugh VK, Jain E, Valiathan A, Nanda R. Interdisciplinary treatment of a periodontally compromised adult patient with multiple missing posterior teeth. Am J Orthod Dentofacial Orthop. 2014 Feb;145(2):238-48.
21. Ahn JC, Lee JH, Yoon JH, Lee JY, Kim JH. Interdisciplinary treatment of a patient with multiple missing teeth and periodontitis. Am J Orthod Dentofacial Orthop. 2018 Feb;153(2):278-89.
22. Nevins M, Wise RJ. Use of orthodontic therapy to alter infrabony pockets. II. Int J Periodontics Restor Dent. 1990;10(3):198-207.
23. Pithon MM. Spontaneous correction of accentuated retraction of maxillary central incisors after autogenous graft in midline, mesialization, and lingual torque of incisor roots. Int J Periodontics Restor Dent. 2018;38(Suppl):s67-s77.

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SPECIAL ARTICLE

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Biostatistics: essential concepts for the clinician

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ABSTRACT

Introduction: The efficiency of clinical procedures is based on practical and theoretical knowledge. Countless daily information is available to the orthodontist, but it is up to this professional to know how to select what really has an impact on clinical practice. Evidence-based orthodontics ends up requiring the clinician to know the basics of biostatistics to understand the results of scientific publications. Such concepts are also important for researchers, for correct data planning and analysis.

Objective: This article aims to present, in a clear way, some essential concepts of biostatistics that assist the clinical orthodontist in understanding scientific research, for an evidence-based clinical practice. In addition, an updated version of the tutorial to assist in choosing the appropriate statistical test will be presented. This PowerPoint® tool can be used to assist the user in finding answers to common questions about biostatistics, such as the most appropriate statistical test for comparing groups, choosing graphs, performing correlations and regressions, analyzing casual, random or systematic errors.

Conclusion: Researchers and clinicians must acquire or recall essential concepts to understand and apply an appropriate statistical analysis. It is important that journal readers and reviewers can identify when statistical analyzes are being inappropriately used.

Keywords: Biostatistics. Statistical analysis. Data presentation. Interactive tutorial.

RESUMO

Introdução: A eficiência dos procedimentos clínicos é baseada em conhecimentos práticos e teóricos. Inúmeras informações diárias estão ao alcance do ortodontista; porém cabe a esse profissional saber selecionar o que realmente tem impacto na prática clínica. A Ortodontia baseada em evidências acaba exigindo que o clínico conheça os fundamentos da bioestatística para compreender os resultados das publicações científicas. Tais conceitos também são importantes aos pesquisadores para um correto planejamento e análise dos dados.

Objetivo: O presente artigo tem como objetivo apresentar, de forma clara, alguns conceitos essenciais da bioestatística que auxiliem o ortodontista clínico na compreensão da pesquisa científica para uma prática clínica baseada em evidências. Além disso, será apresentada uma versão atualizada do tutorial para auxílio na escolha do teste estatístico adequado. Essa ferramenta em PowerPoint® pode ser empregada para auxiliar o usuário a encontrar respostas para dúvidas comuns sobre bioestatística, como o teste estatístico mais adequado para comparar grupos, escolha de gráficos, realizar correlações e regressões, análises de sobrevivência e dos erros aleatório e sistemático.

Conclusão: Pesquisadores e clínicos devem adquirir ou relembrar conceitos essenciais para compreender e aplicar uma análise estatística apropriada. É importante que os leitores e revisores de periódicos possam identificar quando análises estatísticas estão sendo utilizadas de forma inadequada.

Palavras-chave: Bioestatística. Análise estatística. Apresentação de dados. Tutorial interativo.

INTRODUCTION

Every professional, regardless of the area of training, has a role in decision-making based on theoretical and practical knowledge. Regarding health professionals, where it is essential to maintain or promote the health of the patient, any inappropriate decision may cause irreversible biological damage to patients. Currently, Orthodontics has been submitted to an avalanche of new information, technologies and experiences, which are easily accessible. And it is up to the orthodontist to discern the reliable scientific knowledge from those who have errors or bias — acquiring for their clinical practice what will, for example, reduce error rates, waste, unsuccessful therapies and unnecessary exams.[1,2]

Evidence-based Orthodontics can become a challenge for clinicians. This is because published papers often present information that makes understanding scientific knowledge a complex task.[3,4] A substantial level of experience in statistical understanding is necessary in the critical reading of the research, the methodology used, data analysis and interpretation of the results, for the acquisition of conclusions that will reduce the uncertainties in decision making, in view of the variability of available options.[2,5-7]

Statistics are known to have a direct connection to mathematics. And the culture of fear and anxiety that surrounds it makes the assimilation of statistical concepts and methods complex.[8] Some studies show that graduate students, despite understanding the importance of biostatistics, do not have the skills to apply it correctly in scientific research; and that attitudes, successes and failures in face of statistical challenges are linked to basic knowledge.[6,9-11] This ends up having an impact on scientific publications. Studies showed that it is common to find errors such as incompatible study design, inadequate analysis and inconsistent interpretations.[12-14]

The basic concepts, which are fundamental to avoid errors, are often easy to forget, impacting the choice of statistical tests used in the data analysis. In addition, most statistical software does not guide the user in choosing the most appropriate statistical test for the research, generating scientific publications that do not contribute to the solution of a clinical problem, due to the wrong data analysis.[15]

Therefore, the objective of the present article is to clearly review some essential concepts of biostatistics that will assist clinical orthodontists in understanding scientific research for an evidence-based clinical practice, in addition to indicate the main errors observed in published articles. Then, it will be presented the updated version of a PowerPoint® guide, originally published in 2010, to assist in choosing the appropriate statistical test.[16] This guide is useful for readers, authors and reviewers of scientific articles.

BASIC CONCEPTS

Biostatistics is a method used to describe or analyze data obtained from a sample that represents a population. It is used in studies in which variables are related to living beings.[17,18]

WHAT IS A VARIABLE AND HOW IS IT MEASURED?

Variable is a characteristic or condition that can be measured or observed in the sample or population. It can assume different values from one sampling unit to another or in the same unit over time. It is important to know how to classify the variable according to the data it generates. To understand the classifications of the variables regarding the scale used and the type of participation in the study, see Tables 1 and 2, respectively.[8,17,18]

Table 1: Classification of the types of variables according to the scale used.

	NUMERIC OR QUANTITATIVE VARIABLES It is expressed in numbers		NON-NUMERIC, CATEGORICAL OR QUALITATIVE VARIABLE It is expressed in words	
	Discrete	Continuous	Ordinal	Nominal
Concept	It only assumes integer values such as 0, 1, 2, 3, 4 and so on, not allowing fractional values. It is related to counts.	Assumes numeric values both integer and fractional (decimal). It is related to the measurement of quantities.	Represents two or more categories in which the data has ordering or hierarchy.	It represents two or more categories in which there is no order or hierarchy.
Examples	DMFT index; number of erupted teeth.	Cephalometrics measurements; Anterior open bite, in millimeters; Treatment time, in months.	Education level; Pain intensity (absent, low, moderate, severe); Plaque index.	Gender: female or male; Blood type: A, B, AB or O; Angle classification: I, II or III; Questions where the answers can be “yes” or “no”.

Table 2: Classification of the types of variables according to the type of participation in the study.

	DEPENDENT VARIABLE Called “Response Variable”	INDEPENDENT VARIABLE Also known as “Explanatory” or “Predictor”
Concept	It is the event or characteristic that you want to discover or explain. It represents a quantity whose appearance, disappearance, increase, decrease, etc. depends on how the independent variable is handled by the researcher.	It is the determining factor, condition or cause that makes it possible to predict a response, effect or consequence. It can vary during the study or be controlled, but is not affected by any other variable within the experiment.
Example	In one study, it is intended to ascertain the need for orthodontic treatment based on gender, age, education, socioeconomic level and perception of oral health. Thus, the response variable (dependent) of the study is the “need for orthodontic treatment”, while the others are explanatory (independent) variables.	

THE IMPORTANCE OF NORMAL DISTRIBUTION

A distribution in biostatistics refers to a mathematical model that relates values of a variable and the probability of occurrence of each value. It should be clarified that whenever there is a quantitative variable that will be analyzed, it is assumed to verify the normality of the data distribution, by statistical test and/or histogram, according to the need. Some statistical tests require a distribution with normal characteristics as a requisite. Where the data is concentrated around the average and from there they are dispersed in a symmetrical way, with a characteristic bell-shaped graph. When the distribution is different from the normal, preference should be given to the use of median and interquartile deviation.[17-19] The graphical elucidation of normal and abnormal data distributions can be seen in Figure 1.

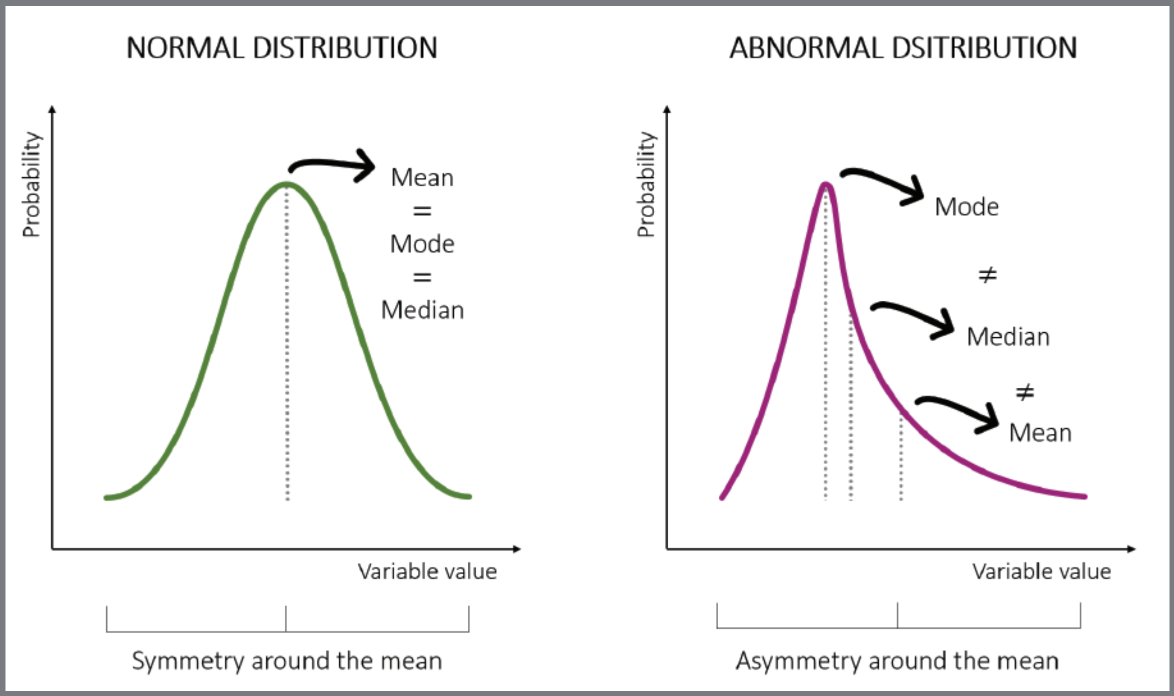

Figure 1: Graphical exemplification of normal and abnormal distributions.

HOW SHOULD THE DATA BE PRESENTED? (DESCRIPTIVE STATISTICS)

The organization and presentation of these data, made by appropriate methods, can be summarized, known as descriptive statistics. This concept is the initial step for an appropriate selection and use of statistical tests. Descriptive statistics can be divided into frequencies and/or summary measures of central tendency and dispersion (Table 3).[8,17,18]

Table 3: Ways of organizing the data in the descriptive analysis.

	FREQUENCY DISTRIBUTION Used for both numeric (quantitative) and non-numeric (qualitative) data. Count of occurrence in the sample by frequency, rate or ratio		SUMMARY MEASURES The summary provides the distribution of data, by central tendency or by variability	
	FREQUENCY	**RATE OR RATIO**	**CENTRAL TENDENCY**	**VARIABILITY**
CONCEPT	**Absolute frequency:** Represents the number of times that each category appeared in the sample. It is the result of counting the number of sample units belonging to each category. **Relative frequency:** Assumes numeric values both integer and fractional (decimal). It is related to the measurement of quantities. It is the division between the absolute frequency of a category and the total frequencies observed. **Percent frequency:** It is the relative frequency multiplied by 100%.	**Rate:** It is the relative frequency multiplied by 1000, 10000 or 100000. **Ratio:** It is the relative frequency of one category divided by the relative frequency of another category.	**Mean:** Is the quotient between the sum of the data and the total number of observations (n). It should be used in quantitative data with normal distribution. **Median:** Represents who is in the middle of the ranked sample. It can be used in non-normal quantitative or ordinal data. When normal distribution is achieved, its value is similar to that of the mean. **Mode:** Represents the most often value. It can be used in any type of variable, but it is of little use in publishing scientific studies	Also known as "dispersion measures", as they reveal how the data varies or is distributed around its midpoint. **Amplitude:** Is the difference between the highest and lowest value in a data set. **Standard deviation (SD):** Is the value that represents the symmetric average dispersion of data around the mean of a data set. It is used in quantitative data with normal distribution. **Variance:** Is the standard deviation value raised to the square. **Variation coefficient:** Is the relative dispersion of the data, represented by the ratio between the standard deviation and the mean, multiplied by 100. **Percentile:** Percentiles are the 99 values that separate a series into 100 equal parts. **Quartile:** Quartile are the values of a series that divide it into four equal parts. First quartile (Q1) includes the first 25% of the data, second quartile or median (Q2) includes the first 50% of the data, third quartile includes the first 75% of the data (Q3). **Interquartile deviation:** Difference between the Q3 (P75) and Q1 (P25), which is not influenced by extreme values. Should be used when non-normal data are being evaluated.

WHY USE STATISTICAL TESTS? (INFERENTIAL STATISTICS)

Inferential statistics allow comparing samples or predicting behaviors of variables. This tool establishes conclusions based on a small portion of a population, with a minimum and previously determined margin of error. Statistical tests are used to quantify the uncertainty of decision making by means of probabilistic principles.[6,17]

Allows the researcher to have a degree of reliability in the statements assumed in the sample, regarding the population. Thus, when the reader realizes that the published study performed statistical tests, he must ask: *"How likely am I to trust these results?"* or *"How much uncertainty is there in the results for an extrapolation of the results (generalization)?"*. These questions should be asked at the beginning of the study, in order to define the chances of error, the confidence and the estimated margins of the population parameter of your sample. The following are the concepts of interest:[6,17-19,20]

1. Significance, or α level (*p*-value):): it represents the chance that the researcher is wrong in stating that there is a difference (or significance), and the difference, in fact, does not exist. Known as type I error or false positive, it can be predetermined at the beginning of the study as 1% or 5%. It can be said that when you have a *p*-value less than the level of significance, then you have a real difference between samples or groups, when applied in groups comparison tests.

2. β error: known as a type II error, or false negative, it represents the chance of the researcher making a mistake in stating that there is no difference when the difference is true. A maximum value of 20% is allowed.

3. Study power (1 – β) : represents the chance for the researcher to be sure that there is a difference when it really exists. It is also defined by the researcher before data collection begins, and is usually at least 80%, or 0.8 (1 – 0.2).

4. Confidence interval: represents the estimate of a sample parameter for a population parameter. Contains upper and lower limits, defined according to the stipulated level of significance. For a 95% confidence interval, we have that for every 100 studies performed, within the same methodology and (n), but with different subjects from the same population, it must be estimated that the population parameter is present in the data distribution of 95 studies. However, there is no need to carry out the 100 studies for this estimate. Just perform a single study and define this interval by 95% CI = mean ± (1.96 x standard error). Therefore, standard error = standard deviation divided by $\sqrt{n}$.

Currently, journals and reviewers have requested in the results not only the *p*-value, but also the referring confidence interval (CI). Some years ago, only a few studies with with multivariate analyzes reported the CI found.[21] A systematic review[22] showed that the interpretation of the CI is important, but it rarely occurs in those randomized clinical trials where the effects of treatments were not statistically significant. This can lead to the abandonment of future research or to a clinical practice based on invalid conclusions.

TYPES OF STUDIES

The execution of a study must always be planned, and this plan for conducting the research is called research design. It must follow specific standards and techniques, according to the nature of the study.[6,17-19]

The quality of research designs is related to the strength of recommendation and applicability to the patient.[18] This difference between the degree of strength of the types of studies can be seen in Figure 2, representing a pyramid of evidence.

This pyramid incorporates the suggestion of Murad et al.[23] that considers not only the study design, but also the assessment of the certainty of the evidence, examined by the GRADE tool (Grading of Recommendations Assessment, Development and Evaluation).[24] So that, for example, a cross-sectional study very well performed can produce a much better quality of results than a case-control study not so well developed, therefore, producing a greater impact on clinical decision. This type of change

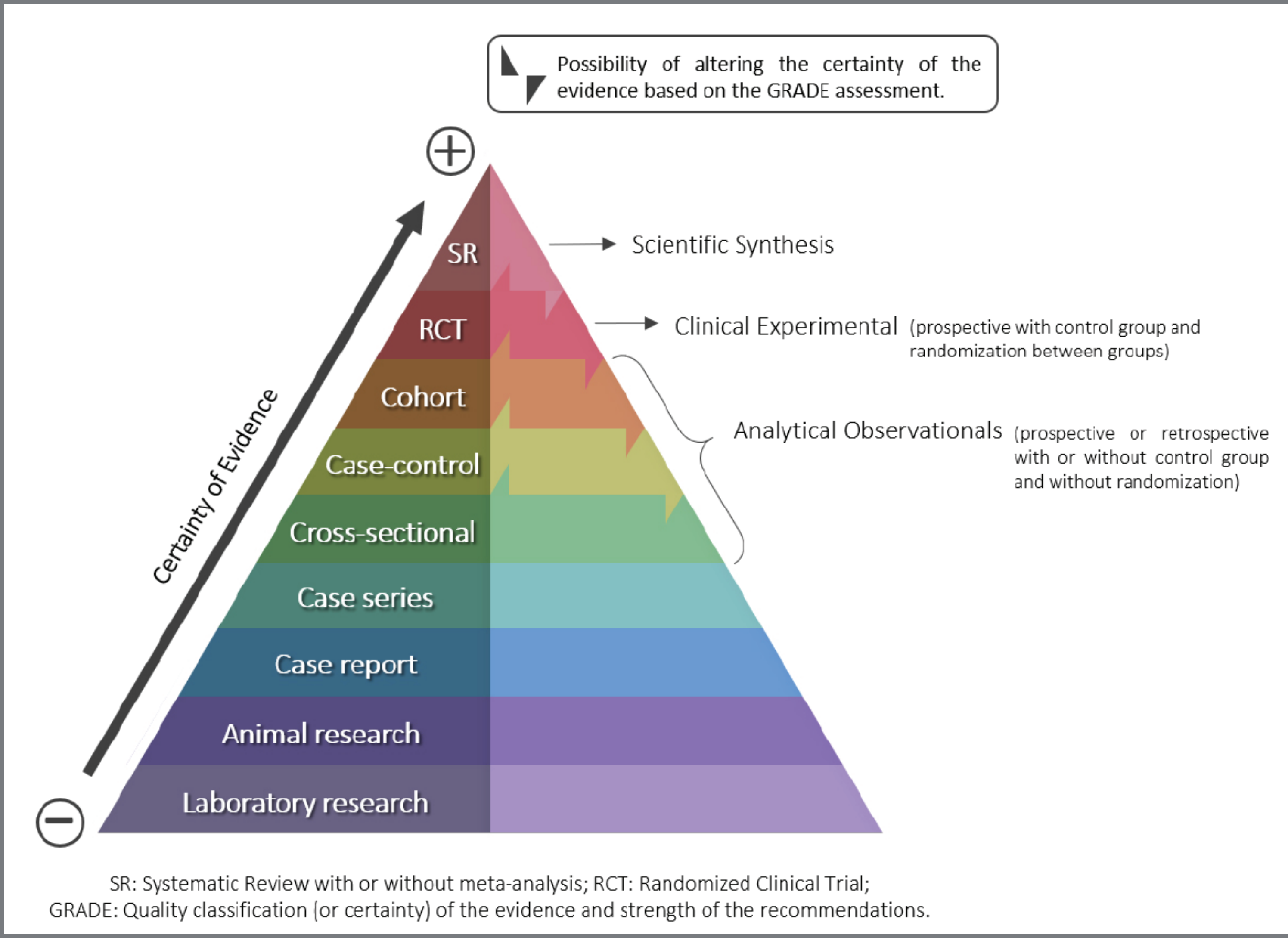

Figure 2: Pyramid of evidence and the types of studies included.

in the strength of the recommendation can occur in studies present from the middle to the top of the pyramid, and will be seen below:[8,18,19]

1. Analytical observational studies: They are studies in which the objective is the observation, description and analysis of variables by means of the comparison of groups. There is no randomization process in the selection of participants, and the exposure was not assigned by the researcher. They are subdivided into three categories, as described bellow.

» Cross-sectional: It is considered a "portrait study". It determines the situation of interest and outcome in a single moment, assessing the prevalence and relationship between variables, comparing exposed and unexposed or with disease and without disease. Example: to analyze the association between gingival inflammation (present/absent) and the use of orthodontic appliance (exposure) in a single moment of treatment, comparing with patients without orthodontic treatment (control).

» Cohort: It is a longitudinal study, considered a "film study". It starts from the exposure to the outcome (disease), and observes over time individuals exposed and not exposed (control group) to a factor — who have not yet developed the outcome of interest —, assessing incidence, carrying out supervised monitoring and establishing etiology and risk factors. Although it is generally prospective, when the data registration coincides with the beginning of the research; there are retrospective cohorts, when the research is initiated after recording the data. Example: analyzing the development of gingival inflammation (incidence) during orthodontic treatment (exposure), with evaluation of gingival condition at the beginning and end of treatment, compared to non-orthodontic patients.

» Case-control: It is also a longitudinal study and evaluates individuals who already have the disease of interest, comparing them with a control group (individuals without the disease), measuring the exposures or interventions performed during the study.

Although it is generally retrospective, they can be carried out prospectively. Example: comparative analysis of orthodontic patients with and without gingival inflammation (disease, or outcome) among patients who did or did not use daily mouthwash. In this case, starts from the disease to the exposure.

2. Randomized Clinical Trial: This is a simulation study of the reality in which an exposure or intervention in the experimental sample occurs, in comparison to a control group. The main feature is the allocation of research subjects being carried out by randomization between groups. It is a highly controlled study. However, the randomization method can fail, especially when small samples are analyzed.

3. Synthesis: This category includes the secondary study called "Systematic Review". It uses primary studies as a source of data to obtain the answer to a key question. It is a scientific investigation carried out under a rigorous methodology for both data searches and analyzes, and the consequent determination of the certainty of the available evidence. When possible, a "meta-analysis" is carried out, which is the statistical analysis to combine the results of the included primary studies. It is at the top of the evidence pyramid for clinical decision-making (Fig 2).

MAIN ERRORS IN THE STATISTICAL METHODOLOGY OBSERVED IN THE PUBLISHED ARTICLES

Articles that will be submitted to journals must be very well written and designed. This requires that the study be conducted in a reliable manner, allowing the correct description of all the steps performed and the consequent ease of reading and acceptance of the article by the reviewers[25]. Below are the most common errors found in published articles, regarding the statistical methodology employed.

USE OF COLUMN / BAR GRAPH FOR QUANTITATIVE VARIABLES

Column graphics should be used for frequency graphics, as each column represents a category. When we have numeric variables, we should use the box-plot graph (Fig 3) for independent samples and the line graph for data over time[8,18]. The box-plot, unlike the column graphic, allows us to observe the summary measure (mean or median) and the dispersion of the obtained values.

USE OF PARAMETRIC TESTS WHEN NORMALITY IS NOT ACHIEVED

Parametric tests are more powerful than non-parametric tests, but they presume a normal distribution of data. Numerical data with abnormal distribution should be analyzed as if they were qualitative data. The use of a parametric test in this situation implies greater ease in rejecting the null hypothesis, which may not represent the population's reality.[8,19]

USE OF MEAN AND STANDARD DEVIATION WHEN THERE IS AN ABNORMAL DISTRIBUTION

Although some researchers correctly use non-parametric tests when the assumption of normality is broken, they sometimes incorrectly use the mean and standard deviation when presenting data.

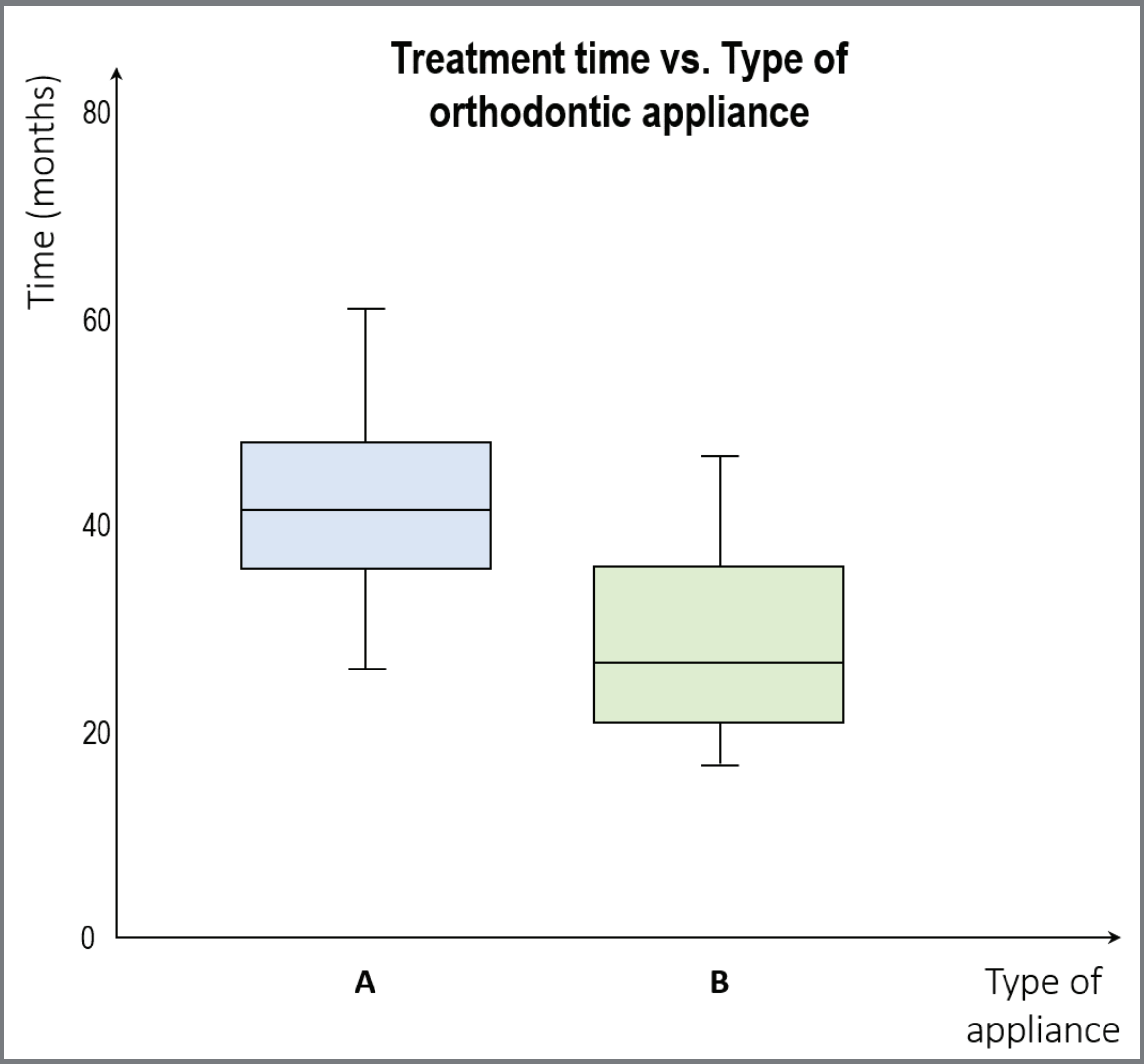

Figure 3: Exemplification of a box-plot type graph of a hypothetical study in which it was sought to assess whether there was a difference in treatment time between two types of orthodontic appliances.

These should not be used exactly due to the asymmetric distribution. In this case, use the nonparametric reference that divides the data in half: the median and its deviation (interquartile deviation).[1,8,17]

OVERSIZED OR UNDERSIZED SAMPLES

Every sample has a minimum number of sample units needed to represent the population. When you have a sample below that quantity (undersized), only large differences can be detected in a significant way. In addition, small samples tend to have an abnormal distribution, which would lead to the use of less robust tests;

while large samples are not practical, since they increase the cost and time required for the study.[17,18]

A GUIDE TO ASSIST IN CHOOSING THE APPROPRIATE STATISTICAL TEST

In order to obtain a reliable statistical result that allows extrapolation to the population of interest, it is extremely important to know which test is the most suitable for the study. A PowerPoint® guide to assist in choosing the statistical test was published in 2010[16], and since then it has been widely used by countless researchers. With more than 244 thousand accesses (02/10/2021), this is the article with the highest number of downloads in the SciELO collection for the dentistry area. The version 2020 3.0 presents a new layout and has additional multivariate analyzes. In addition, this version provides the paths for running the tests on several free software, such as Jamovi (version 1.2, Sydney, Australia) and BioEstat (version 5.3, Amazonas, Brazil), as well as on the website www.vassarstats.net (VassarStats, Richard Lowry - United States). The download can be done according to the preferred language (Portuguese, English or Spanish), through the following link:

http://www.ppgo.propesp.ufpa.br/index.php/br/programa/noticias/todas/176-tutorial-teste-estatistico-para-pesquisa-cientifica

The use is simple and must be done in the "presentation mode". The INITIAL MENU represents the objective intended by the researcher. There are six possible options (Fig 4), where it is possible to arrive at the desired answer through a sequence of clicks on drops.

By clicking on the option "Examine the type of distribution", you have the direct answer of which test you can perform to examine the distribution of data for a quantitative variable. The same occurs when clicking on the drop "Survival analysis", in which the possible options for survival tests are directly available.

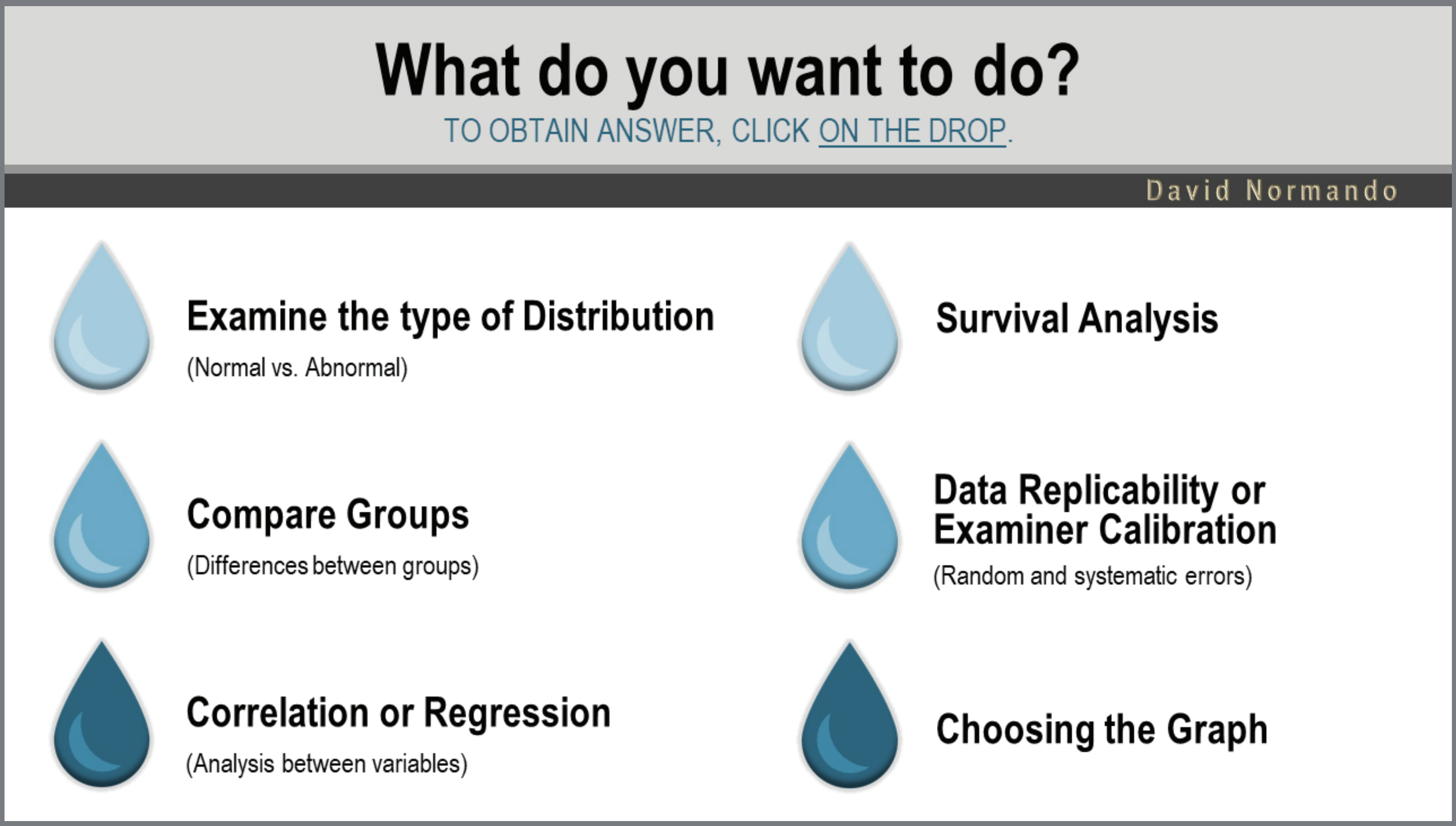

Figure 4: Initial menu of the tutorial.

In the other options of the initial menu, there is a hyperlink to the submenus:

» ***Comparison menu:*** allows obtaining the specific statistical test for the difference between two or more paired or independent samples with or without normal distribution.

» ***Correlation menu:*** indicates the analyzes for correlation and/or modeling between two or more variables.

» ***Replicability menu:*** indicates the measurement accuracy tests for the analysis of random and systematic errors.

» ***Graphic menu:*** provides the researcher with the appropriate graph for the type of sample and objective of the study.

So that, after a sequence of clicks on drops, it is possible to obtain the desired response. Figure 5 exemplifies a submenu — in this case, the comparison.

This sequence of clicks requires basic knowledge about types of variables (Table 1) and data distribution (Fig 1). It is also necessary to understand the difference between dependent (paired) and independent (unpaired) samples. Paired samples are those in which the comparison is dependent on

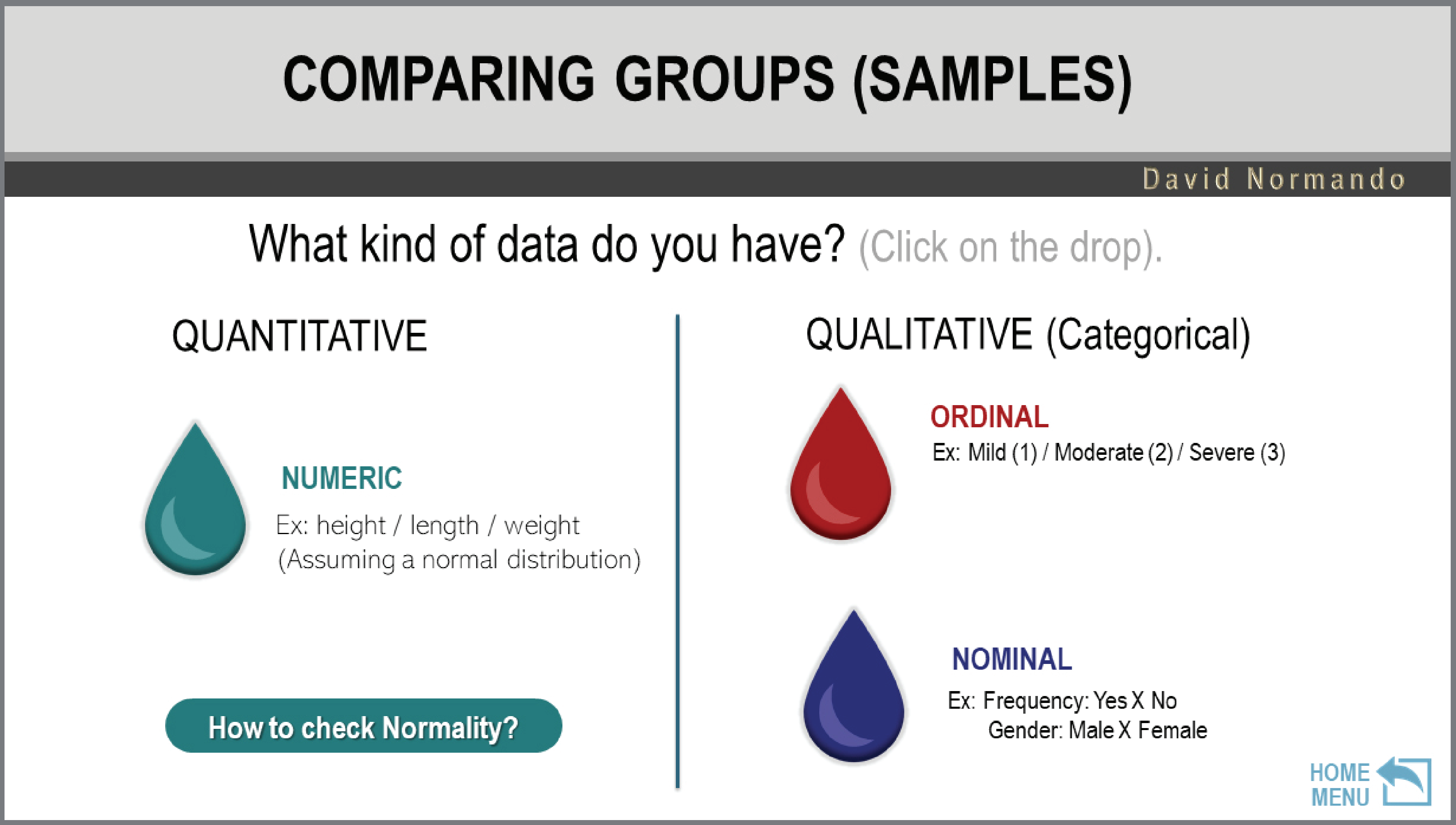

Figure 5: Example of a tutorial submenu.

the same individual (before *vs.* after; right *vs.* left; T1 *vs.* T2 *vs.* T3). Independent samples are those in which there is a comparison between different individuals. After identifying the desired answer, you can obtain the test execution path in both BioEstat (not available in the English version) and Jamovi, and, in some cases, in VassarStats, by clicking on the corresponding icon that will appear (Fig 6).

Figure 6: Icons that represent the execution path of the Jamovi, Bioestat, and Vassarstats software.

In this update, when you click on an item by mistake, it is possible to return to the submenu in which it was already found, providing greater agility during use.

CONCLUSION

It is important that readers and reviewers of journals can identify when a research uses inadequate statistical analysis, disregarding fundamental concepts. The new version of the "Tutorial for choosing the test" presented is a path to the most appropriate use of statistical tests, allowing the correction of wrong choices.

AUTHORS' CONTRIBUTION

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Conception or design of the study:

DT, DN.

Data acquisition, analysis or interpretation: DT, DN.

Writing the article:

DT, DN.

Critical revision of the article:

DT, DN.

Final approval of the article:

DT, DN.

Overall responsibility:

DN.

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REFERENCES

1. An TL, Cuochi OA. Utilization of statistics in orthodontia. Rev Dent Press Ortod Ortop Facial. 2004;9(6):97-108.
2. Silva GAR. The decision-making process in clinical practice: medicine as a state of the art. Rev Soc Bras Clin Med. 2013;11(1):75-9.
3. Rumsey D. Most used hypothesis tests. In: Rumsey D, editor. Statistics for dummies. Rio de Janeiro: Alta Books; 2010. p. 237-47.
4. Schneider LR, Pereira RPG, Ferraz L. Evidence-based practice in the context of primary health care. Saúde Debate. 2018;42(118):594-605.
5. Mariano MTS, Januzzi E, Grossmann E. Scientific evidence-based orthodontics: incorporating science into clinical practice. Rev Dent Press Ortod Ortop Facial. 2009;14(3):107-13.
6. Polychronopoulou A, Eliades T, Taoufik K, Papadopoulos MA, Athanasiou AE. Knowledge of European orthodontic postgraduate students on biostatistics. Eur J Orthod. 2011;33(4):434-40.
7. Rodrigues CF, Lima FJC, Barbosa FT. Importance of the proper use of basic statistics in clinical research. Rev Bras Anestesiol. 2017;67(6):619-25.
8. Hernandez JAE, Santos GR, Silva JO, Mendes SLL, Ramos VCB. Evidence of validity of the anxiety scale in statistics in psychology students. Psychol Science Prof. 2015; 35(3):659-75.

9. El Tantawi MM. Factors affecting postgraduate dental students' performance in a biostatistics and research design course. J Dent Educ. 2009;73(5):614-23.

10. Murthykumar K, Veeraiyan DN, Prasad P. Impact of video based learning on the performance of postgraduate students in biostatistics: a retrospective study. J Clin Diagn Res. 2015;9(12):ZC51-ZC3.

11. Chowdhury SK. Prior knowledge, sex and students' attitude towards statistics: a study on postgraduate education students. Am J Educ Res. 2018;6(3):270-6.

12. Lucena C, Lopez JM, Pulgar R, Abalos C, Valderrama MJ. Potential errors and misuse of statistics in studies on leakage in endodontics. Int Endod J. 2012;46(4):323-31.

13. Gates S, Ealing E. Reporting and interpretation of results from clinical trials that did not claim a treatment difference: survey of four general medical journals. BMJ Open. 2018;9:e024785.

14. Velez FGS, Pinto CB, Chalita M, Falcao D, Fregni F, Amorim R. Avoiding mistakes while writing scientific manuscripts in medical and health sciences. Geriatr Gerontol Aging. 2016;10(2):49-56.

15. Mann PS. Introduction to statistics. 5ª ed. Rio de Janeiro: LTC; 2006.

16. Normando D, Tjaderhane L, Quintão CCA. A powerpoint-based guide to assist in choosing the suitable statistical test. Dental Press J Orthod. 2010;15(1):101-6.

17. Padovani CR. Biostatistics. Sao Paulo: Academic Culture; 2012.

18. Estrela C. Scientific methodology. 2ª ed. Porto Alegre: Medical Arts; 2005.

19. Demathé A, Silva ARS, De Carli JP, Goiato M, Miyahara G. Evidence-based dentistry: optimizing practice and research. RFO UPF. 2012;17(1):96-100.

20. Zientek LR, Yetkiner OZE, Ozel S, Allen J. Reporting confidence intervals and effect sizes: collecting the evidence. Career & Technical Education Research. 2012;37(2):277-95.

21. Polychronopoulou A, Pandis N, Eliades T. Appropriateness of reporting statistical results in orthodontics: the dominance of P values over confidence intervals. Eur J Orthod. 2011;33(1):22-5.

22. Gewandter JS, McDermott MP, Kitt RA, Chaudari J, Koch JG, Evans SR, et al. Interpretation of CIs in clinical trials with non-significant results: systematic review and recommendations. BMJ Open. 2017;7(7):e017288.

23. Murad MH, Asi N, Alsawas M, Alahdab F. New evidence pyramid. Evid Based Med. 2016;21(4):125-7.

24. Atkins D, Eccles M, Flottorp SA, Guyatt GH, Henry D, Hill S, et al. Systems for grading the quality of evidence and the strength of recommendations I: critical appraisal of existing approaches The GRADE Working Group. BMC Health Serv Res. 2004;4(1):38.

25. Faber J. Writing scientific manuscripts: most common mistakes. Dental Press J Orthod. 2017;22(5):113-7.