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QUALITY OF LIFE IS SIMILAR BETWEEN FIXED APPLIANCES AND INVISALIGN USERS

The role of orthodontic treatment in improving patients' quality of life is well known. In the past, orthodontic treatment only focused on the esthetics of the smile. However, recent publications have found that these treatments also improve quality of life, thus enhancing their importance. Today, one cannot think of orthodontics without thinking of orthodontic aligners. Much has been said about the esthetic improvements of these devices. However, evidence of aligners' other

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benefits in terms of function, stability, and quality of life remains inconclusive. Thus, Canadian researchers developed a study that aimed to compare quality of life in users of fixed orthodontic appliances and aligners.[1] The researchers recruited adolescent patients under active treatment for a minimum of six months with Invisalign or fixed appliances. In total, 74 patients (37 in each treatment group) participated in the study. These patients answered a questionnaire that assessed quality of life. The authors found that both treatment groups were very satisfied with their treatment modality, and their quality of life was similar.

EXCESSIVE FORCE ON MOLAR INTRUSIVE MOVEMENT DOES NOT INCREASE THE AMOUNT OF ROOT RESORPTION

The intrusive movement of molars is one of the most difficult types of dental movement. In the not-so-distant past, intruding posterior teeth was a nearly impossible task. However, thanks to the advent of skeletal anchorage devices, intrusion supported by mini-implants and miniplates has become routine in orthodontic offices. However, the ideal amount of force to achieve this movement without damaging the tooth structure remains unknown. To address this, Egyptian researchers developed a randomized controlled clinical study[2] comparing root resorption resulting from the intrusion of maxillary posterior teeth using two different magnitudes of force. Adult patients with skeletal open bite and indication of dentoalveolar intrusion were recruited and randomly divided into two groups. The control group received 200g of intrusive force, and the experimental group received 400g (Fig 1). Based on the results, the authors concluded that root resorption was inevitable with orthodontic intrusion. However, increased intrusive force did not increase resorption.

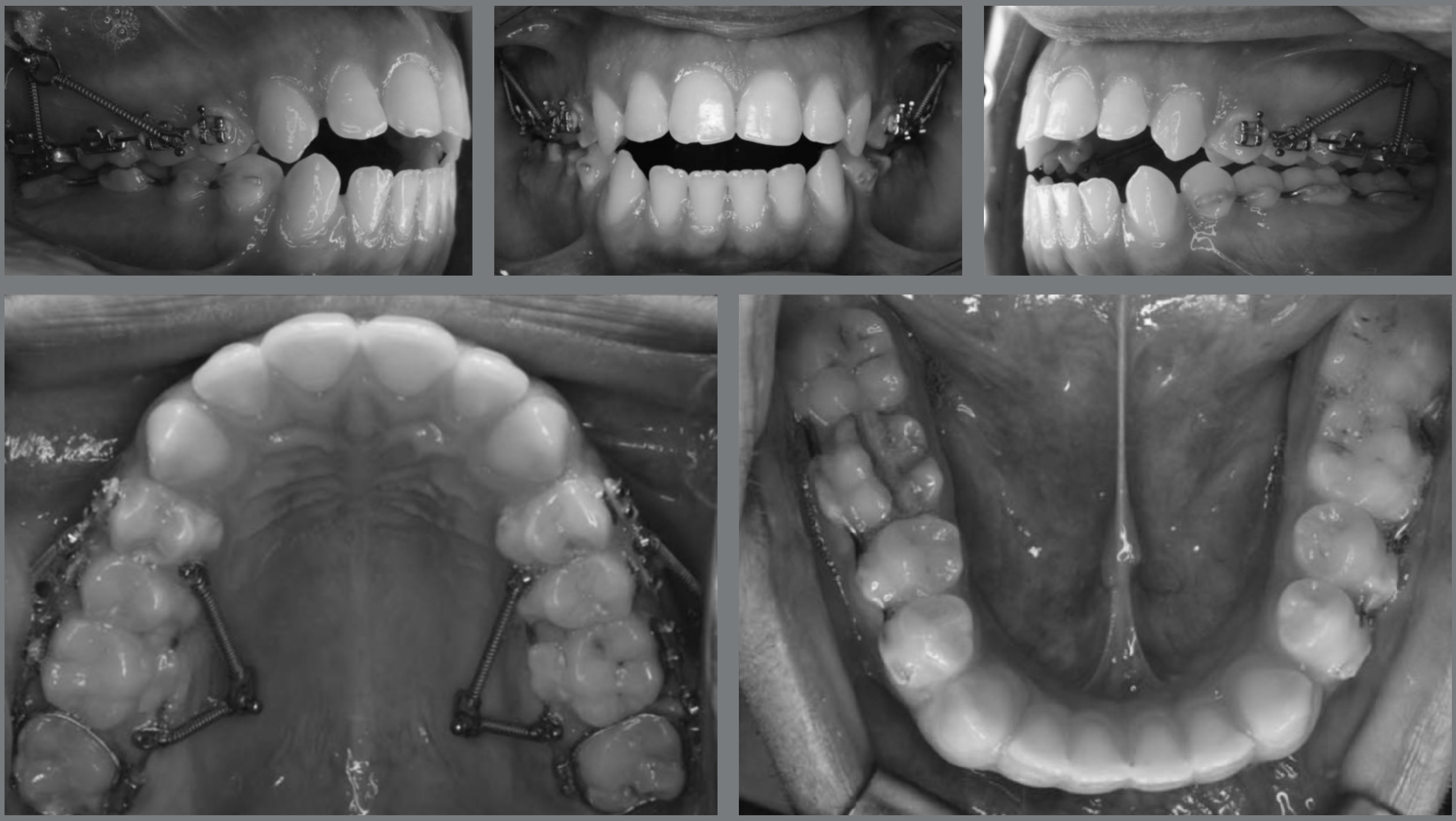

Figure 1: Appliance assembly showing the infra-zygomatic and palatal miniscrews and closed coil springs applying intrusive force on the maxillary posterior segments. Source: Akl et al.[2], 2021.

INVISALIGN IS INEFFICIENT FOR CORRECTION OF CLASS II MALOCCLUSION

The relentless search for aesthetically pleasing orthodontic appliances resulted in the development of orthodontic aligners by Kesling in 1945. Aligners became popular as they received more publicity and technology advanced. Aligners are seen by many as a successor to conventional fixed appliances. However, scientific literature evaluating this treatment modality is scarce. Uncertainty remains about how much correction can be achieved with aligners. Recently, a group of American researchers and one Brazilian researcher developed a study[3] that aimed to determine whether Class II malocclusion can be treated with Invisalign orthodontic aligners. A sample of 80 adult patients using Invisalign was divided into two groups: one with Class I malocclusion and the other with Class II malocclusion. To evaluate the treatment, seven measures adopted by the American Board of

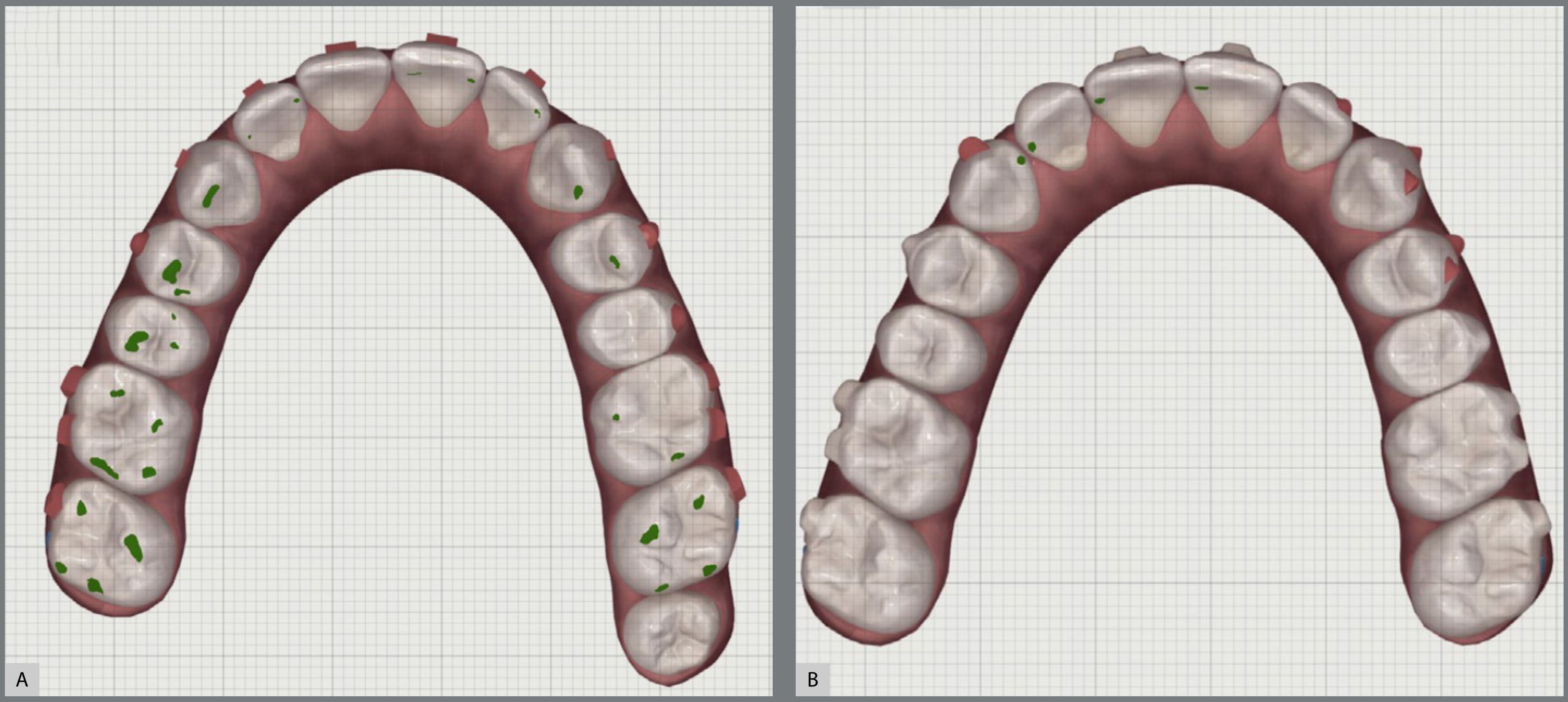

Figure 2: Occlusal contacts: **A)** before treatment; **B)** after treatment. Source: Patterson et al.[3], 2021.

Orthodontics were used to evaluate anteroposterior and vertical dimensions. The initial measurements, a prediction by ClinCheck (Align Technology), and the post-treatment measurements (Fig 2) were compared. The results revealed that the amount of anteroposterior correction in patients with Class II malocclusion was 6.8% of the predicted value. The amount of overbite correction achieved was 28.8% and 38.9% of the predicted values in patients with Class I and Class II malocclusion, respectively. The authors also noted that no patient with Class II malocclusion would meet the American Board of Orthodontics standards after treatment with Invisalign.

OVERJET CORRECTION CHANGES PATIENTS' POSTURE

It has become scholarly consensus that orthodontic corrections not only improve smile esthetics, but also improve patients' general and mental health. For example, the scientific literature reports that early treatment of children with severe malocclusion, especially Angle Class II malocclusion, prevents trauma to the incisors and positively influences orthopedic malformations. However, this nascent area requires more research. To advance knowledge in this area, a group of German researchers developed a study[4] with the objective of analyzing the relationship between body posture and overjet in children before and after orthodontic treatment with removable functional orthodontic appliances (Fig 3). For this study, 54 patients with increased overjet (> 9 mm) were recruited, and their body posture was assessed before and after orthodontic treatment. Open bite and crossbite cases were excluded. The authors concluded that the reduction in overjet during early orthodontic treatment may be associated with a detectable effect on pelvic torsion.

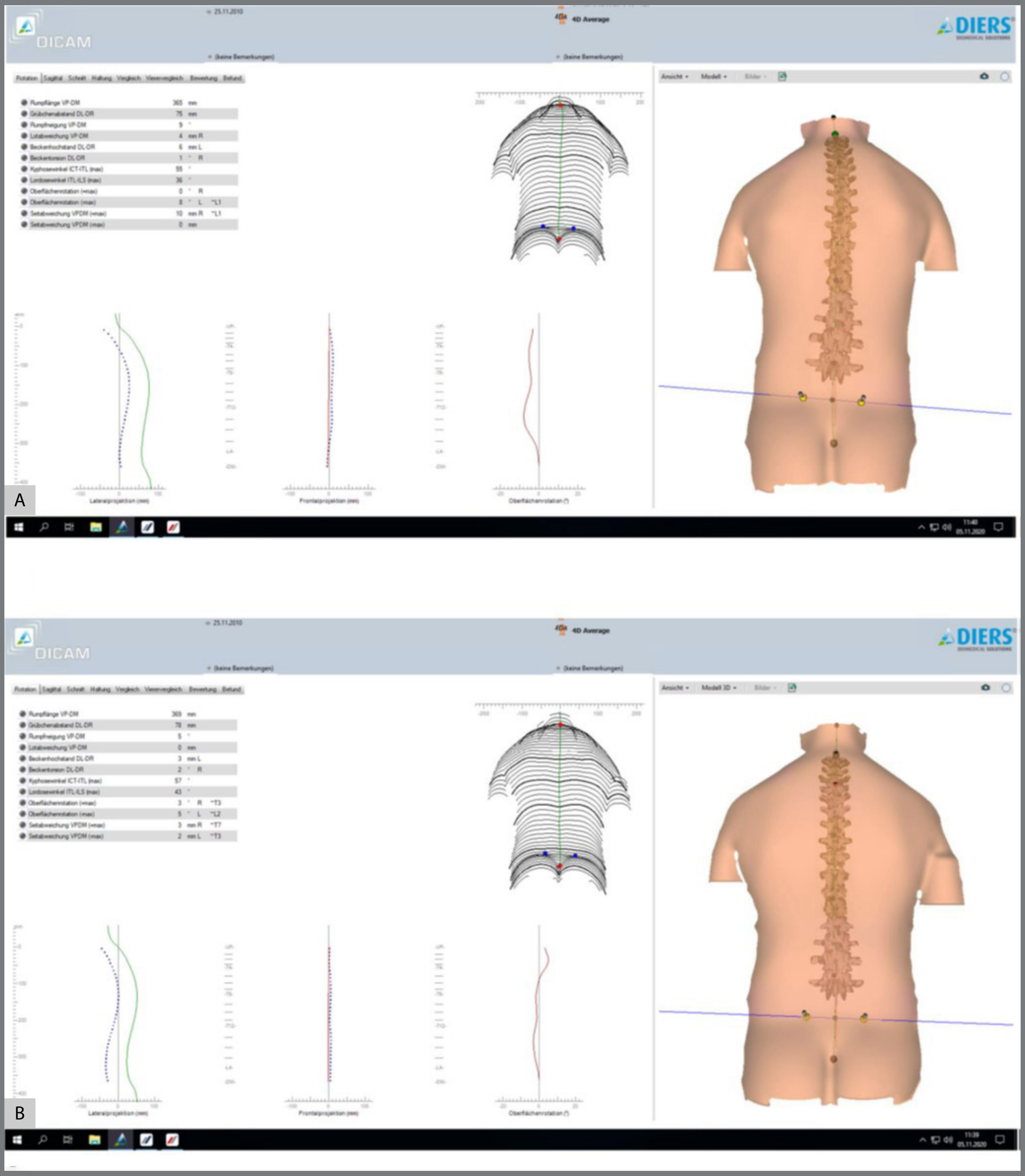

Figure 3: Rasterreographic measurement of a sample patient before **(A)** and after **(B)** early orthodontic treatment. Source: Klostermann et al.[4], 2021.

MOBILE ORTHODONTIC APPLIANCES MADE OF ACRYLIC RESIN CAUSE CHROMOSOMAL DAMAGE

Acrylic resins have many applications in orthodontics, from the prevention and interception phases through treatment and containment of orthodontic results. Despite the various methods used in polymerizing acrylic resins, the monomer-to-polymer conversion is never complete, resulting in the release of monomers into the oral cavity during its use. The presence of residual monomers can alter the resins' final physical properties and lead to local and systemic tissue reactions. These reactions can manifest as local chemical irritation, hypersensitivity, and mucosal inflammation. The genotoxic potential of methyl methacrylate is not fully understood, and research in this area is needed because genetic damage at an early age can lead to the development of health problems later in life. Thus, Brazilian researchers developed a study[5] aiming to investigate the occurrence of chromosomal damage and degenerative nuclear changes indicative of apoptosis and necrosis in exfoliated cells of the mouth and palate mucosa of children and adolescents using orthodontic appliances made of acrylic resin. Micronuclei and nuclear alterations were evaluated in cells collected from the cheeks and palates of 30 patients of both sexes, aged between 6 and 12 years. Cell evaluations were performed before device installation and 15 to 21 days after installation. The results revealed that direct contact of orthodontic appliances made of acrylic resins with the oral mucosa increases the incidence of chromosome damage and degenerative nuclear alterations.

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ORTHODONTIC INSIGHT

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Supernumerary teeth in patients with cleft lip and palate: the tooth germs do not separate

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ABSTRACT

Introduction: Supernumerary teeth in cases of cleft lip and palate do not result from the division of normal germs before the formation of hard tissue. Deciduous and permanent teeth odontogenesis begins after the face has formed, either with or without the cleft.

Discussion: The most acceptable hypothesis to enable understanding of the presence of supernumerary teeth on one or both sides of the cleft palate is hyperactivity of the dental lamina in its walls. This hyperactivity, with the formation of more tooth germs, must be attributed to mediators and genes related to tooth formation, under strong influence of local epigenetic factors, whose developmental environment was affected by the presence of the cleft.

Conclusion: The current concepts of embryology no longer support the fusion of embryonic processes for the formation of the face, but rather the leveling of the grooves between them. All human teeth have a dual embryonic origin, as they are composed of ectoderm and mesenchyme/ectomesenchyme, but this does not make it easy for them to be duplicated to form supernumerary teeth.

Keywords: Supernumerary tooth. Hyperdontia. Cleft lip and palate.

RESUMO

Introdução: Os dentes extranumerários nas fissuras labiopalatinas não são resultado da divisão dos germes normais antes da formação do tecido duro. A odontogênese dos decíduos e permanentes inicia-se depois de formada a face, com ou sem fissuras.

Discussão: A hipótese mais plausível para compreender a presença dos dentes extranumerários em um ou nos dois lados da fissura labiopalatina é a hiperatividade da lâmina dentária em suas paredes. Essa hiperatividade, com formação de mais germes dentários, deve ser atribuída aos mediadores e genes relacionados à formação dos dentes, sob forte influência de fatores epigenéticos locais, cujo ambiente de desenvolvimento foi afetado pela presença da fissura.

Conclusão: Os conceitos atuais da embriologia não fundamentam mais a fusão de processos embrionários para a formação da face, e sim o nivelamento dos sulcos entre eles. Todos os dentes humanos têm uma dupla origem embrionária, pois se compõem de ectoderma e mesênquima/ectomesênquima, mas isso não facilita sua duplicação para formar dentes extranumerários.

Palavras-chave: Dente extranumerário. Hiperdontia. Dente supranumerário. Fissuras labiopalatinas.

The most frequent supernumerary teeth are the mesiodens, mandibular premolars and Bolk's fourth molars. When they resemble the group of origin, they are denominated eumorphic supernumerary teeth, and when they have an undefined shape, they are said to be dysmorphic. In cleft lip and palate patients, the frequency of supernumerary teeth reaches up to 43.5% of cases[1-5] (Fig 1).

FORMATION OF THE FACE DOES NOT OCCUR BY FUSION

The formation of the face does not occur by fusion of embryonic processes, which was an older way of understanding how facial development takes place. All evidence has shown that the face is formed by leveling of the embryonic processes, except at a very specific and central point of the hard palate, from which anterior and posterior leveling is also established.[6]

These concepts, of face formation mechanisms, and their evolution — from the fusion to the leveling — have been meticulously reviewed, described and presented in an article published in 2017[6] (Figs 2 and 3).

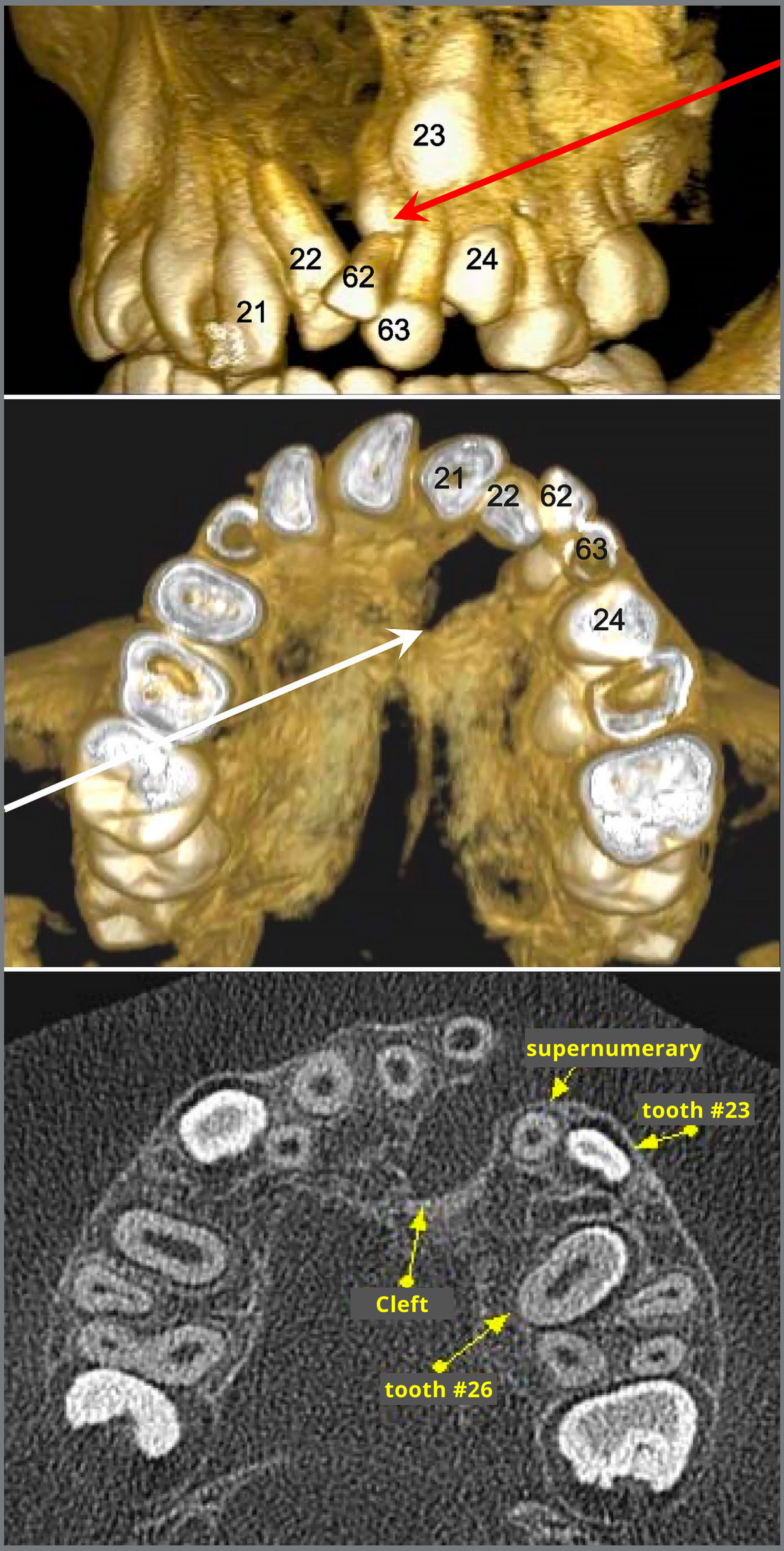

Figure 1: Example of a supernumerary tooth (red arrow) in front of the canine and at the margin of the cleft palate (white arrow) in tomographic images (Source: Freitas[20], 2007).

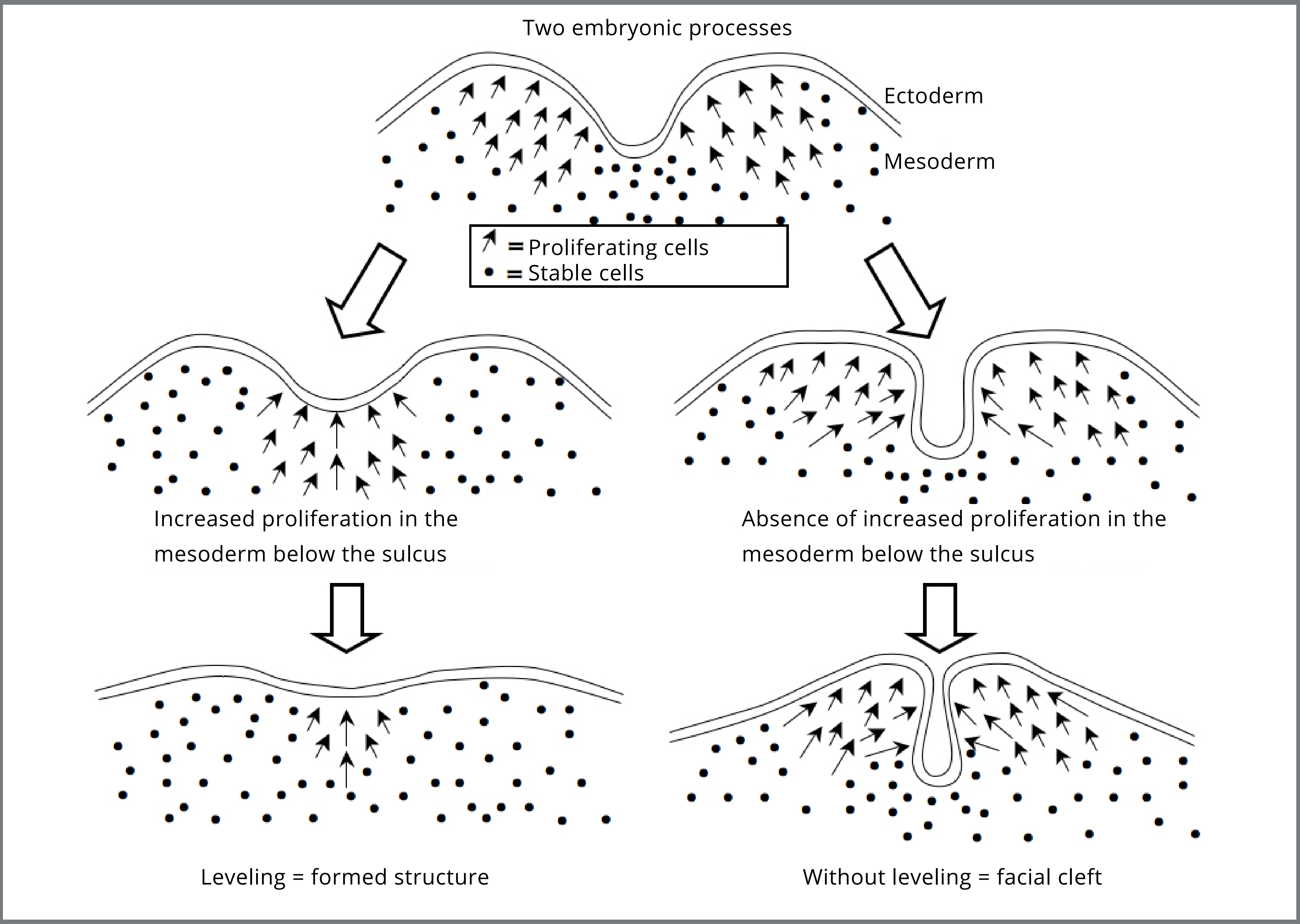

Figure 2: Diagram of the leveling of facial embryonic processes, on the left; and when facial cleft occurs due to lack of leveling, on the right (Source: Consolaro et al.[6], 2017).

Etiopathogenesis of some cystic diseases and lesions based on the non-fusion of processes is no longer accepted. Many of these diseases continue to be considered clinical entities, as their true etiopathogenesis has been discovered; others were diseases such as the odontogenic keratocyst, which develops in areas where fusions of embryonic processes supposedly occurred, and were not fissure lesions or cysts.[7-11]

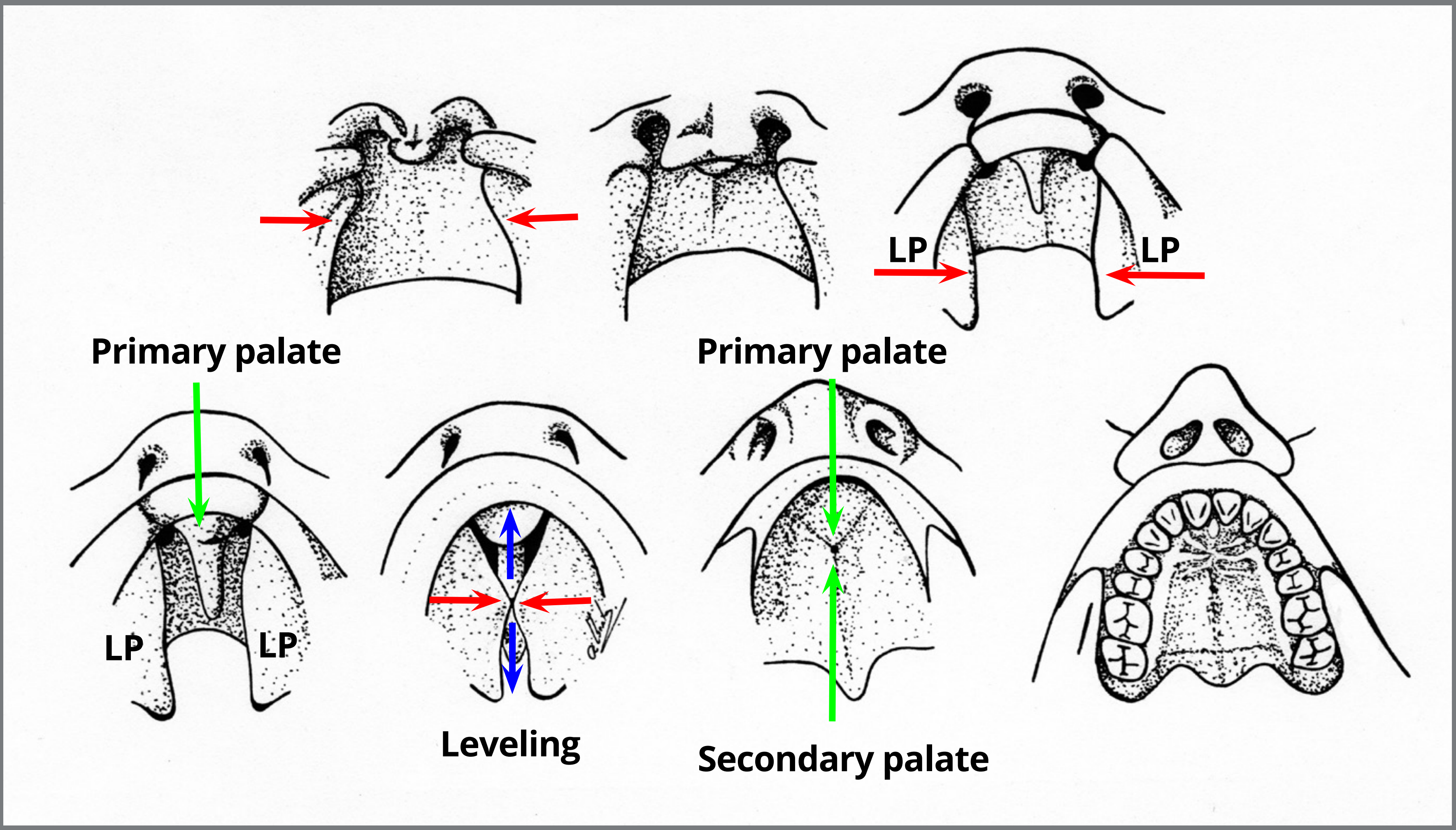

Figure 3: Diagram of palate formation: the two lateral palatal processes (LP) meet in the midline at a certain point (red arrows), the only point where the disappearance of the ectoderm is present, with integration or fusion of the two mesoderms. After this point, leveling (blue arrows) for anterior and posterior occurs, ending the secondary palate and complementing the primary palate (Source: Consolaro et al.[6], 2017).

WHEN THE DENTAL LAMINA AND TOOTH GERMS BEGIN

The anterior part of the primitive mouth, or stomodeum, has an ectodermal lining of the external part that invaginates. This lining joins with the lining at the back of the mouth — which, in the embryo, is called the embryonic pharynx.[12] When the buccopharyngeal membrane is broken, the two cavities join to form the final mouth. The exact site in the oral mucosa where this membrane adheres is still controversial.

The first sign of deciduous human dentition occurs around the eighth week of embryonic life, with a linear thickening in the lining and a horseshoe-shaped contour at the location of the future dental arch.[13] This thickening will form the dental lamina that descends vertically as it enters the space that will be the mandible and maxilla. Underlying this thickening, there is an increase in the concentration of mesoderm and ectomesenchymal cells derived from the neural crest, that will later form the dental papilla and dental follicle.

This thickening of the ectodermal lining initially occurs at the region of the incisors and molars in each quadrant, which will unite, as they grow towards the anterior and posterior directions, and become equal in the region that will be the canines.

These two areas are influenced by the same mediators and tooth-related genes (Fgf-8, Pitx-2, Shh, Msx-1, Pax-9, Bmp-4), without specific differences between one and the other, as shown by Kriangkrai et al.[14] At a certain point, the fact that these two areas have not yet become equalized or met does not mean that there was no fusion,[15,16,17] because the face is formed by the leveling of embryonic processes by a proliferative phenomenon.

All these above-mentioned characteristics and occurrences are relative to the deciduous lateral incisor, and not the permanent lateral incisor. From the deciduous lamina, sprouts or buds will form, which will give rise to the germs of the deciduous teeth and to another lamina that arise by lingual, and will give rise to the permanent teeth — which is also called the successional lamina, and is continuous around the entire dental arch.

But there is a most important point: the first signs of formation of this successional lamina that will give rise to permanent teeth only begin to appear after the eleventh week of embryonic life.[6,13] As mentioned before, the deciduous teeth odontogenesis begins after the eighth week, when the formation of the face and palate has been completed. The non-leveling of the processes and establishment of the cleft occurs before odontogenesis begins.

The lack of closure by leveling and the formation of the cleft represent local epigenetic factors very important in the generation of dental anomalies in the region, including the supernumerary teeth. The chronology of formation of the deciduous and permanent teeth can be retrieved in the studies conducted by Massler, Schour and Poncher,[18,19] in 1941 and 1946, with still up to date figures, tables and illustrative diagrams.

HYPOTHESES TO EXPLAIN SUPERNUMERARY TEETH, INCLUDING IN CASES WITH CLEFTS

The cause of supernumerary teeth is unknown. There are theories or hypotheses to explain them, highlighting the following:

1. The hyperactivity of the dental lamina, represented by excessive induction for this laminar and continuous tissue to form more tooth buds than the normal number. This can occur due to an excessive quantity of growth factors or mediators, especially in the areas of clefts, which lead to more teeth appearing than were originally programmed by the genes.
2. Atavism, or phylogenetic reversal, which represents current manifestations of distant ancestral characteristics — as a possible occurrence of third dentition, which has never been described or observed in primates and predecessors of the human race. This theory represents a theoretical and very imaginative presumption.
3. The sectioning, into two or more parts, of a tooth germ prior to the formation of hard or mineralized tooth tissue, but due to an unknown cause that has never been demonstrated *in vivo*.
4. Some cases of supernumerary teeth are familiar, but heredity is not necessarily linked to the etiopathogenesis in the majority of cases. Heredity as a factor in supernumerary teeth still needs to be further investigated, but randomness does occur in almost all cases.

CLEFT LIP AND PALATE DO NOT OCCUR CONCOMITANTLY WITH THE BEGINNING OF ODONTOGENESIS

On the lateral walls of cleft palate, there is frequent presence of supernumeraries in the form of a extra lateral incisor on the side corresponding to the premaxilla or as a tooth similar to the lateral incisor on the maxillary side of the cleft, also identified as precanine.[1-5] These teeth may also be dysmorphic, as they do not have the morphology of the dental group that gave rise to them, but their tissues are microscopically indistinguishable from eumorphic and normal teeth.

An explanation often given for these supernumerary teeth in clefts is that the supposed lack of fusion — an event that could never be demonstrated, even in a rudimentary way — would cleave the tooth germ into two parts, thus giving rise to two independent teeth, with one of them being supernumerary. In the formation of clefts, no cleavage occurs, and there is no external force that separates the structures, such as the maxilla and the teeth, which have already been formed. In this period, the teeth have not yet been formed.

It is difficult to imagine this occurring, as the formation of the face by leveling, or even if it was by fusion, occurs between the fourth and eighth week of embryonic life, while the first traces or tissue changes for the formation of the band and dental lamina that will give rise to permanent teeth occur from the eleventh week.

The phenomena of formation of the face and the cleft lip and palate, and the presence of tooth germs — even the germs of deciduous maxillary lateral incisors — do not occur concomitantly. In the case of permanent teeth, the formation of germs occurs much later than the occurrence of clefts, which occurs at a much earlier stage than the formation of the dental lamina of permanent teeth, called the successional lamina.

The leveling of embryonic processes means their gradual increase by proliferation of the mesoderm at the bottom of the grooves, depressions and valleys formed between them, thereby leveling the surfaces. Embryonic processes are protuberances and elevations that level out at the top of their projections (Figs 2 and 3). Hyperactivity of the dental lamina is suggested to be the explanation for the supernumerary teeth, which could be increased by the accentuated epigenetic factors in the cleft palate area.

ALL TEETH ARE OF DUAL EMBRYONIC ORIGIN

The formation of sprouts or buds that will form tooth germs at each point corresponding to a tooth occurs by cell differentiation that is induced by mediators such as growth factors, which are peptides that have this function in an organism in the process of formation. These mediators activate odontogenesis genes in the ectoderm and mesenchyme.[14]

The lack of leveling of the medial nasal process with the maxillary process leads to the occurrence of cleft between the maxilla and premaxilla. The initial foci of this differentiation, in the incisor and molar region, as previously mentioned, continue to expand forwards and in a posterior direction, even if there is a previously established cleft.

In the region of the cleft palate, the two separate parts will continue to receive stimuli from the mediators to give rise to tooth germs. On both sides of the dental lamina and both sides of the future maxillary lateral incisor germ, the embryonic origin is the same. The topography and location of a structure does not determine its embryonic origin, but rather to which embryonic layer those cells belong. All teeth will always have an ectodermal and mesenchymal origin.

The fact that the maxillary lateral incisor is derived from the site where the medial nasal process was leveled, and the canine is derived from the area that was topographically derived from the maxillary process, does not imply that lateral incisor and canine have a distinct or different embryonic origin. The embryonic origin or nature has to do with being derived from the ectoderm, mesoderm and endoderm, and even being of ectomesenchymal origin, as in the case of all human teeth.

The fact that the deciduous maxillary lateral incisor arises from one or another facial embryonic process does not distinguish or modify its embryonic origin or its nature, especially if we consider that the mechanism of fusion of embryonic processes is not scientifically supported: There is no evidence of these fusions, obtained by means of any analysis or methodology.[6] All evidence shows that leveling of embryonic processes takes place, not fusion. Unfortunately, many studies, although recent, have tried to explain the embryonic phenomena of the face and teeth based on the theoretical model of the fusion of processes.

Probably, the activity on each side of the cleft, or hyperactivity of the dental lamina, explains why an supernumerary maxillary lateral incisor is sometimes formed on the side of the premaxilla, and, at the same time, another supernumerary lateral incisor in the region anterior to the canine — which has, therefore, been called the pre-canine supernumerary. In many cases of cleft lip and palate there are no supernumerary teeth, and in others only one of these two types of supernumerary teeth occurs.

FINAL CONSIDERATIONS

The location and organization of dental buds in the dental lamina occur by induction of mediators called growth factors, which act and activate the genes of odontogenesis.[14] Hyperactivity represented by more mediators and an increased response to them may plausibly explain the formation of supernumerary tooth buds and germs, irrespective of whether they occur in cleft areas or not.

As the times of formation of the face and the chronology of odontogenesis do not occur concomitantly, this does not allow us to affirm that the formation of a cleft lip and palate cleaves or severs the germ of the maxillary lateral incisor, in order to give rise to supernumerary teeth that are so common in these cases. On both sides of a cleft lip and palate, mediator induction continues normally and may induce supernumerary formation, by local lamina hyperactivity at these separate ends or interfaces.

AUTHORS' CONTRIBUTION

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Conception or design of the study:
AC, IAO.
Data acquisition, analysis or interpretation:
AC, MCMM, DAOM, IAO.
Writing the article:
AC, MCMM, DAOM, IAO.
Critical revision of the article:
AC, MCMM, DAOM, IAO.
Final approval of the article:
AC, MCMM, DAOM, IAO.
Overall responsibility:
IAO.

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Stress and displacement of mini-implants and appliance in Mini-implant Assisted Rapid Palatal Expansion: analysis by finite element method

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ABSTRACT

Objective: In this study, simulations were performed by the finite element method (FEM) to determine the tension and displacement in mini-implants and in expander appliance during rapid maxillary expansion, by varying the number and location of the mini-implants.

Methods: For the computational simulation, a three-dimensional mesh was used for the maxilla, mini-implants and expander appliance. Comparisons were made on six different Mini-implant Assisted Rapid Palatal Expander (MARPE) configurations, by varying the amount and location of mini-implants. A closed suture was design and received two activations of 0.25 mm, and an open suture had a 0.5-mm aperture that received 20 activations, also of 0.25 mm.

Results: For the closed suture, the maximum displacement values in the mini-implants were between 0.253 and 0.280 mm, and stress was between 1,348.9 and 2,948.2 MPa; in the expander appliance, the displacement values were between 0.256 and 0.281 mm, and stress was between 738.52 and 1,207.6 MPa. For the open suture, the maximum displacement values in the mini-implants were between 2.57 and 2.79 mm, and stress was between 5,765.3 and 10,366 MPa; in the appliance, the maximum displacements was between 2.53 and 2.89 mm, and stress was between 4,859.7 and 9,157.4 MPa.

Conclusions: There were higher stress concentrations in the mini-implant than in the expander arm. In the simulations with a configuration of three mini-implants, stress overload was observed in the isolated mini-implant. Displacements of the mini-implants and arms of the appliance were similar in all simulations.

Keywords: Palatal expansion technique. Finite element method. Orthodontic anchorage procedures. Orthodontic appliances.

RESUMO

Objetivo: Realizar simulação pelo método de elementos finitos (MEF) para determinar a tensão e o deslocamento dos mini-implantes e do aparelho expansor durante a expansão rápida da maxila, variando a quantidade e localização dos mini-implantes.

Métodos: Para realização da simulação computacional, foi utilizada uma malha tridimensional para a maxila, mini-implantes e aparelho expansor. As comparações foram feitas em seis configurações de MARPE (*Mini-implant Assisted Rapid Palatal Expander*), com quantidades e localização diferentes dos mini-implantes. Foram modeladas uma sutura fechada, que recebeu duas ativações de 0,25 mm, e outra sutura com abertura de 0,5 mm, que recebeu 20 ativações, também de 0,25 mm.

Resultados: Para a sutura fechada, os valores máximos de deslocamento nos mini-implantes foram entre 0,253 e 0,280 mm, e as tensões, entre 1348,9 e 2948,2 MPa; e no aparelho expansor, os valores de deslocamento foram entre 0,256 e 0,281 mm, e as tensões, entre 738,52 e 1207,6 MPa. Para a sutura aberta, os valores máximos de deslocamento nos mini-implantes foram entre 2,57 e 2,79 mm, e as tensões, entre 5.765,3 e 10.366 MPa; e no aparelho os deslocamentos máximos foram entre 2,53 e 2,89 mm, e as tensões, entre 4.859,7 e 9.157,4 MPa.

Conclusões: Ocorreram maiores concentrações de tensão no mini-implante do que no braço do aparelho expansor. Nas simulações com configuração de três mini-implantes, foi observada sobrecarga de tensão no mini-implante isolado. Os deslocamentos dos mini-implantes e braços do aparelho foram semelhantes em todas as simulações.

Palavras-chave: Técnica de expansão palatal. Análise de elementos finitos. Procedimentos de ancoragem ortodôntica. Aparelhos ortodônticos fixos.

INTRODUCTION

Mini-implant Assisted Rapid Palatal Expander (MARPE) is an appliance for correction of maxillary atresia in adults as an alternative to surgical procedures.[1–5] The mechanical behaviour of the mini-implants and expander appliance during maxillary disjunction is important, especially due to the heavy forces applied to perform the procedure.[6] The number of mini-implants required for MARPE varies according to the technique and the clinical indication: appliance configurations with two or four mini-implants are more commonly observed.[1-4,7,8]

The finite element method (FEM) is a valuable resource for investigating orthodontic mechanics.[9-11] Stress and strain simulations using the FEM have been shown to be useful for improving the MARPE behavior. For example, hybrid expanders with two mini-implants for anchorage,[9] the effects on the nasomaxillary complex[11] and, recently, a comparison between mono- and bicortical anchorage using the MARPE[12] have been examined.

A clinical reality faced by the orthodontist is the possibility of losing the anchorage mini-implant during the active period of treatment. Faced with situations like that, what should the orthodontist do? The main goal of this study is to determine the stress and displacement of mini-implants and expander appliance by FEM, during rapid maxillary expansion, for different numbers and locations of mini-implants.

MATERIAL AND METHODS

A maxillary model was produced in SolidWorks® 2015 (Waltham, MA, USA) based on the three-dimensional mesh from a computed tomography image.[13] After making the maxillary model, the following orthodontic accessories were designed: mini-implants 2 mm in diameter and 10 mm in length (Morelli Ortodontia, Sorocaba, São Paulo, Brazil), and the structure of the appliance to apply expansion displacement. Figure 1 presents the tetrahedral-element three-dimensional mesh model and boundary conditions associated with orthodontic appliances, and the number and position of mini-implants.

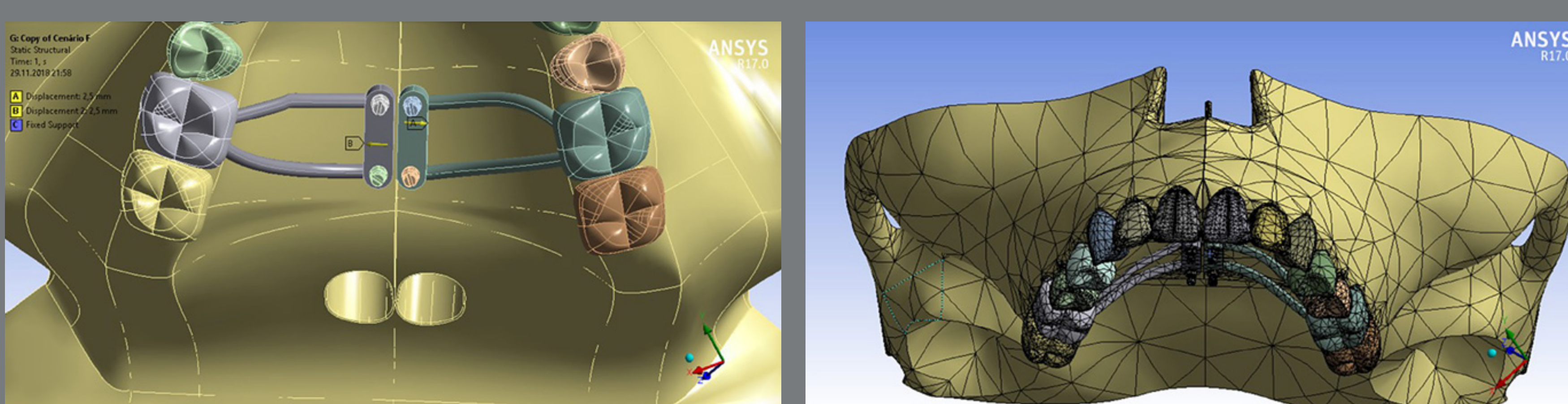

Figure 1: Three-dimensional model and boundary conditions associated with orthodontic appliances.

The material considered for the mini-implants was Ti-6Al-4V alloy, and stainless steel (AISI 304) was considered for the expander appliance. The application of conventional mini-implants, and not those indicated to MARPE, may represent a selection bias, however they are appliances previously used to perform the technique.[4] The elastic modulus of the suture was estimated according to connective tissue and bone values. All the materials simulated in the models were considered to have linear mechanical behavior, using the Young's modulus (MPa) and Poisson's coefficient as properties for the simulations. The properties of the materials used are described in Table 1.[9,12,14-16]

Table 1: Mechanical properties of the materials used in the models.

Material	Young's modulus (MPa)	Poisson coefficient
Tooth	20.700	0.30
Periodontal ligament	0.71	0.40
Bone	14.700	0.30
Stainless steel	190.000	0.29
Mini-implant	114.000	0.34

Two types of suture were designed for the simulations: a completely closed suture, representing the phase before suture opening, and another with the hemi-maxillas separated by a 0.5 mm-thick cut.[12] The open suture did not contain any embolization or interdigitation, so that there is no medial palatal resistance to the expanding force, representing the phase after rupture of the suture.

A 0.5-mm displacement was performed in two 0.25-mm activations in the closed suture model to activate the appliance. In the open suture, a 5-mm displacement of the expander appliance was performed in 20 activations of 0.25 mm.[12]

The tests were performed on two-, three- and four-anchor mini-implants at different locations, as shown in Figure 2: in A) two anterior mini-implants (1 and 2); B) one anterior and one posterior mini-implant on opposite sides (1 and 4); C) two posterior mini-implants (3 and 4); D) three mini-implants, two of them being anterior (1, 2 and 3); E) three mini-implants, two posterior (1, 3 and 4); F) four mini-implants.

Some boundary conditions were adopted for the simulation. The first was to consider as a fixed support the posterior region of the model, to avoid rotation of the structure when displacements were performed. For the contact between the model elements, the condition of bonded contact was adopted so that there was no type of slip between the parts.

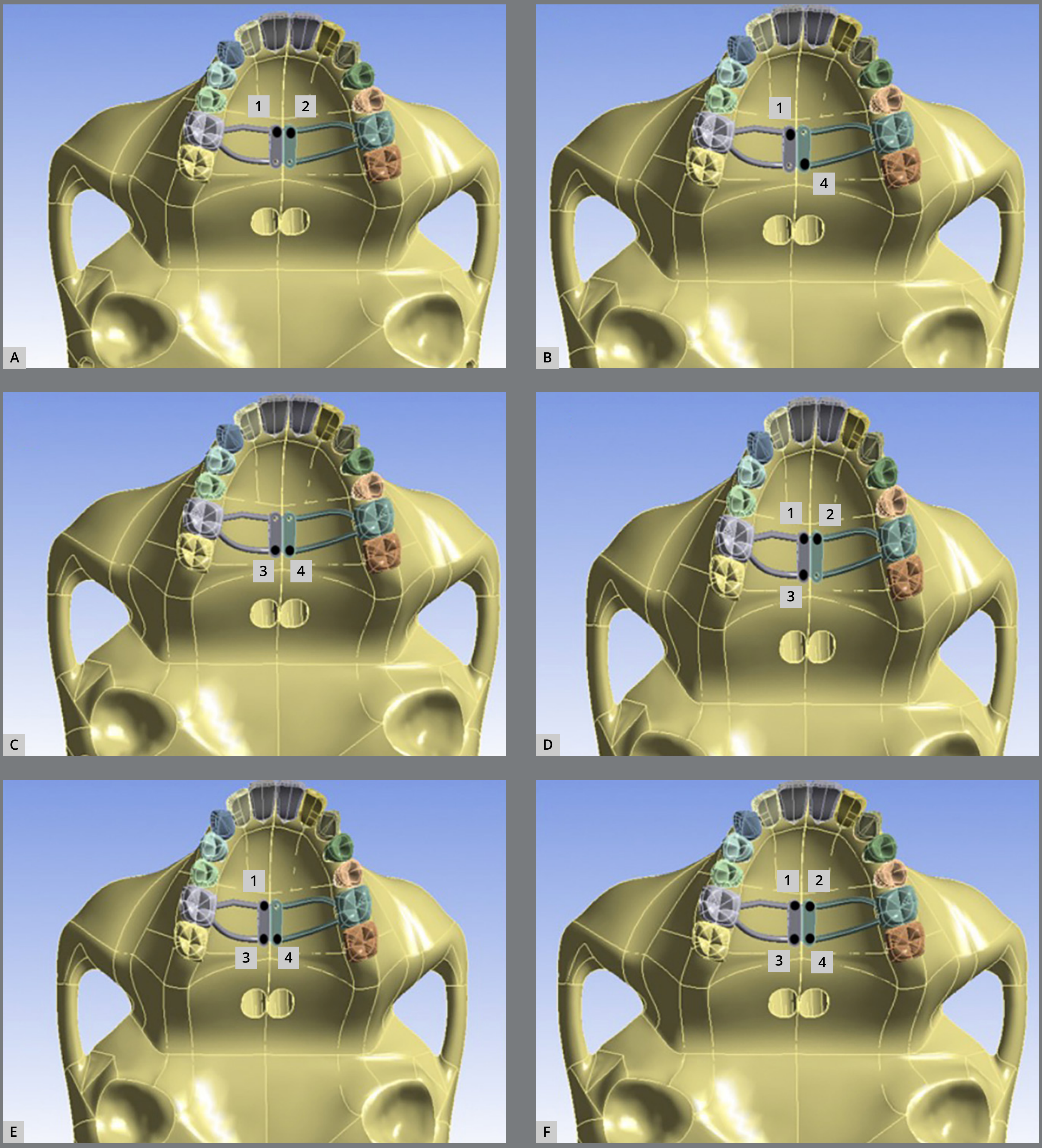

Figure 2: A) Two anterior mini-implants; **B)** one anterior and one posterior mini-implant on opposite sides; **C)** two posterior mini-implants; **D)** three mini-implants, two of which being anterior; **E)** three mini-implants, two posterior; **F)** four mini-implants.

The model was exported to ANSYS R17.0 (Ansys, Inc., Canonsburg, USA), and the geometry was subdivided into 137,817 tetrahedral elements with 251,164 nodes, forming a three-dimensional arranged mesh. The mesh nodes are the connection point between the elements. Each node has a degree of displacement that can be performed in the three dimensions (x, y and z).

RESULTS

Tables 2 and 3 present the results of the maximum stress (MPa) and displacements (mm), respectively, in the mini-implants and of the expander appliance arm in the closed midpalatal suture model. The maximum stress values were between 1,348.9 and 2,948.2 MPa, as can be seen in Figure 3, which presents the von Mises stress distribution in the mini-implants. The displacements observed were between 0.253 and 0.280 mm, as shown in Figure 4. For the simulations considering the open midpalatal suture model (Tables 4 and 5), the stress values in the mini-implants ranged from 6,190.6 to 10,366 MPa, according to the von Mises stress distribution presented in Figure 5. The displacements observed were between 2.57 and 2.79 mm (Fig 6). Solitary mini-implants on one side showed a significantly higher stress peak than the others, in the simulations of closed and open suture models with three mini-implants (D and E). In the open and closed suture simulations, the group with four mini-implants (F) presented smaller and more balanced values than that with two mini-implants (A, B and C).

Table 2: Maximum stress (MPa) in the mini-implants and in the expander appliance arms according to the quantity and location of mini-implants in the closed palatine suture simulation.

	Quantity and location of mini-implants					
	A	B	C	D	E	F
Mini-implant 1	2,062.4	1,803.1		1,656.8	1,348.9	1,982.1
Mini-implant 2	2,440.0			2,917.1		2,475.3
Mini-implant 3			2,199.1	1,391.7	1,943.1	2,208.9
Mini-implant 4		1,939.3	2,659.4		2,948.2	2,624.0
Right arm	814.48	826.81	957.0	1,011.1	1,091.6	892.91
Left arm	1,049.5	1,069.3	1,207.6	664.0	738.52	856.71

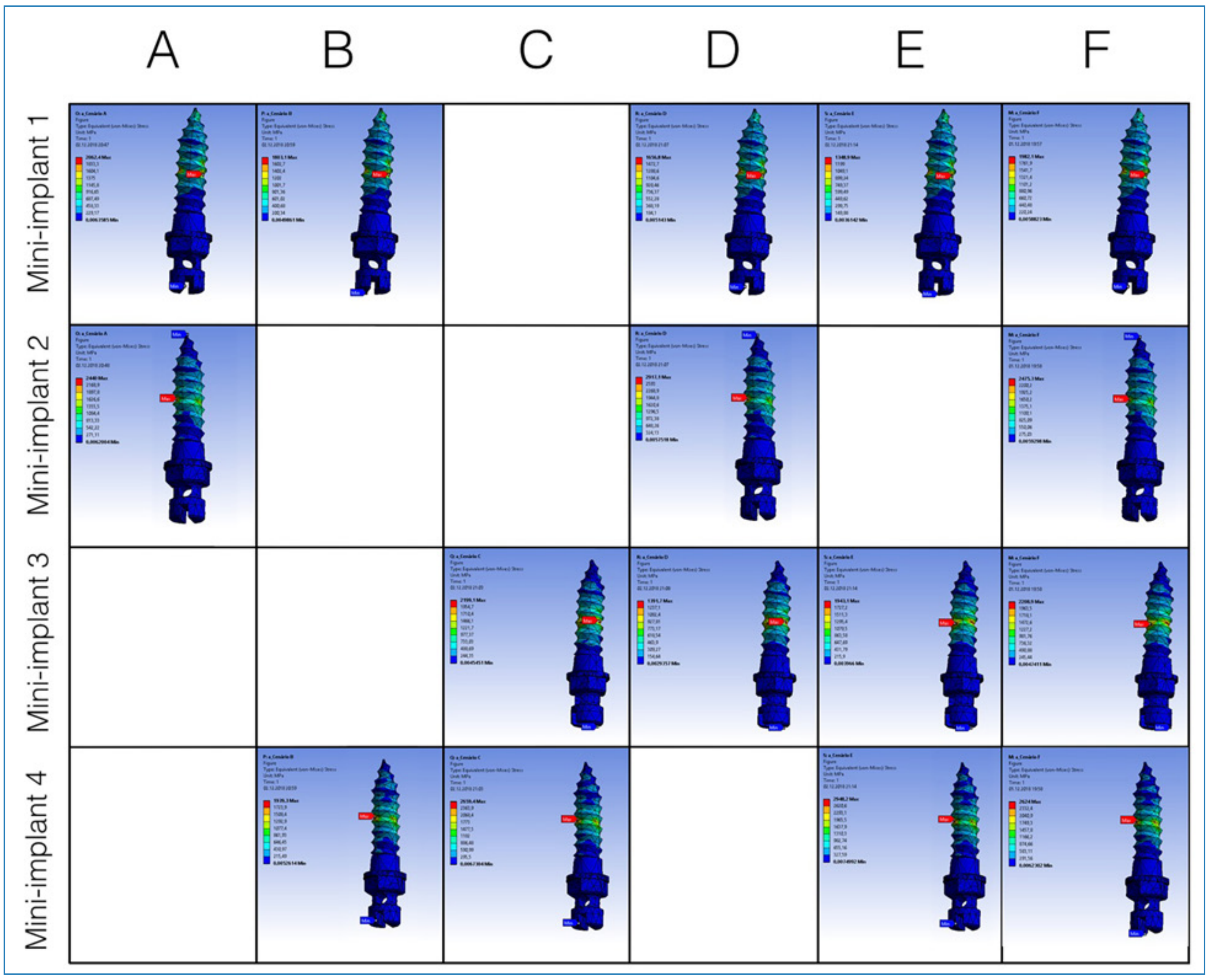

Figure 3: Tension distribution for closed midpalatal suture.

Table 3: Displacements (mm) of the mini-implants and of the expander appliance arms according to the quantity and location of mini-implants in the closed palatine suture simulation.

	Quantity and location of mini-implants					
	A	B	C	D	E	F
Mini-implant 1	0.275	0.273		0.259	0.259	0.261
Mini-implant 2	0.272			0.280		0.265
Mini-implant 3			0.261	0.257	0.280	0.263
Mini-implant 4		0.261	0.265		0.262	0.266
Right arm	0.272	0.271	0.269	0.281	0.266	0.258
Left arm	0.271	0.271	0.269	0.253	0.256	0.256

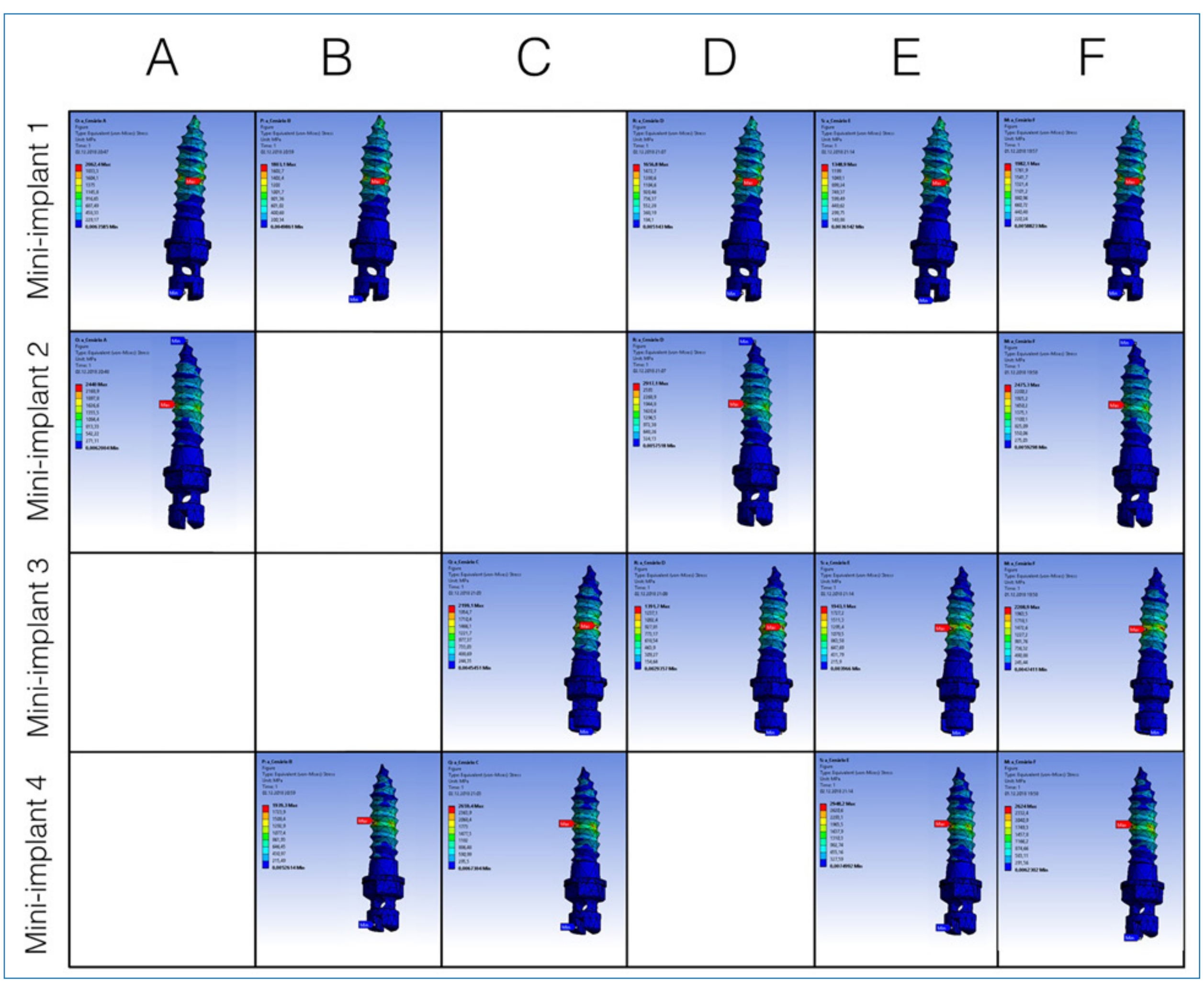

Figure 4: Displacement distribution for closed midpalatal suture.

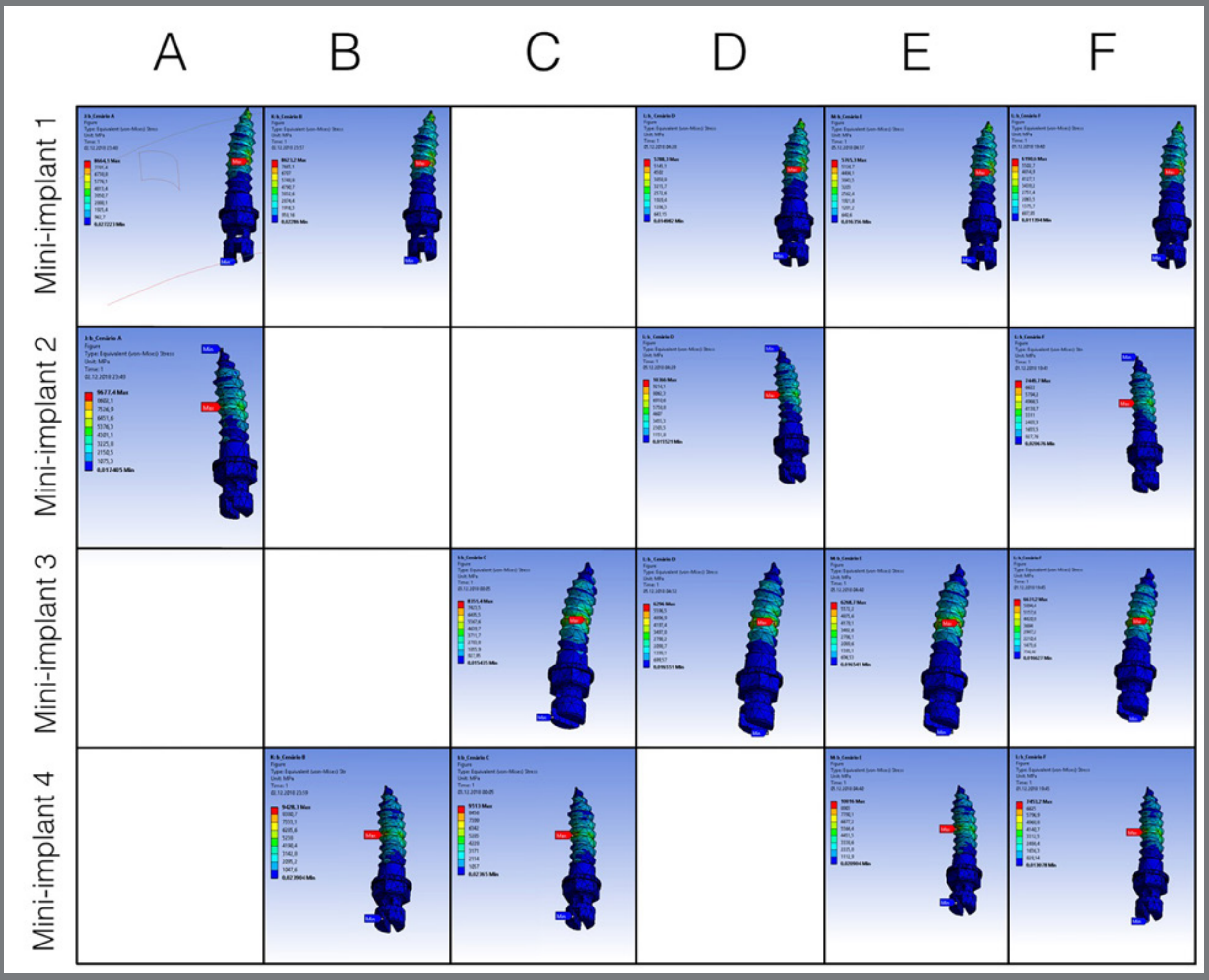

Figure 5: Tension distribution for open midpalatal suture.

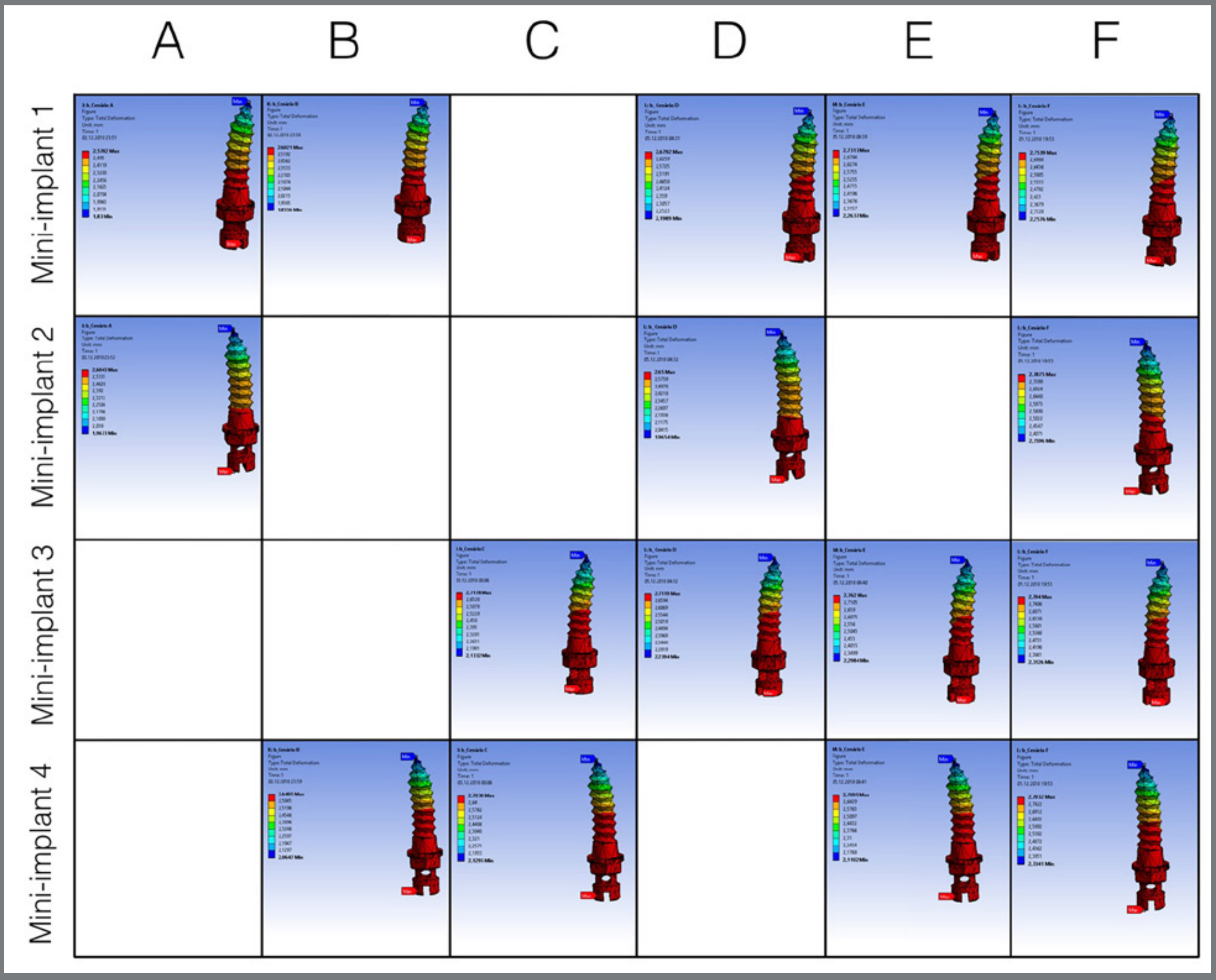

Figure 6: Displacement distribution for open midpalatal suture.

Table 4: Maximum stress (MPa) in the mini-implants and in the expander appliance arms according to the quantity and location of mini-implants in the simulation of open palatine suture.

	Quantity and location of mini-implants					
	A	B	C	D	E	F
Mini-implant 1	8,664.1	8,623.2		5,788.3	5,765.3	6,190.6
Mini-implant 2	9,677.4			10,366.0		7,449.7
Mini-implant 3			8,351.4	6,269.0	6,268.7	6,631.2
Mini-implante 4		9,428.3	9,513.0		10,016.0	7,453.2
Right arm	4,859.7	7,214.6	7,334.6	5,212.4	7,615.8	5,514.4
Left arm	5352	5,251.6	9,157.4	6,614.0	6,663.6	6,876.3

Table 5: Displacements (mm) of the mini-implants and of the expander appliance arms according to the quantity and location of mini-implants in the simulation of open palatine suture.

	Quantity and location of mini-implants					
	A	B	C	D	E	F
Mini-implant 1	2.57	2.60		2.67	2.73	2.75
Mini-implant 2	2.60			2.65		2.78
Mini-implant 3			2.71	2.71	2.76	2.79
Mini-implant 4		2.64	2.70		2.70	2.79
Right arm	2.56	2.63	2.69	2.60	2.70	2.87
Left arm	2.53	2.55	2.71	2.83	2.89	2.86

In the arms of the expander appliance, the maximum stress observed was between 738.52 and 1,207.6 MPa, and displacement ranged from 0.256 to 0.281 mm (Fig 7) in the closed palatine suture simulations. For the analyses with open midpalatal suture, the maximum stress observed was between 5,212.4 and 9,157.4 MPa, and maximum displacement was between 2.53 and 2.87 mm (Fig 8). Although the highest concentrations of stress occurred close to the mini-implant contact and expander appliance, the arm segment of the expander appliance near contact with the molar also presented considerable stress in all simulations performed, in both the open suture and closed suture models.

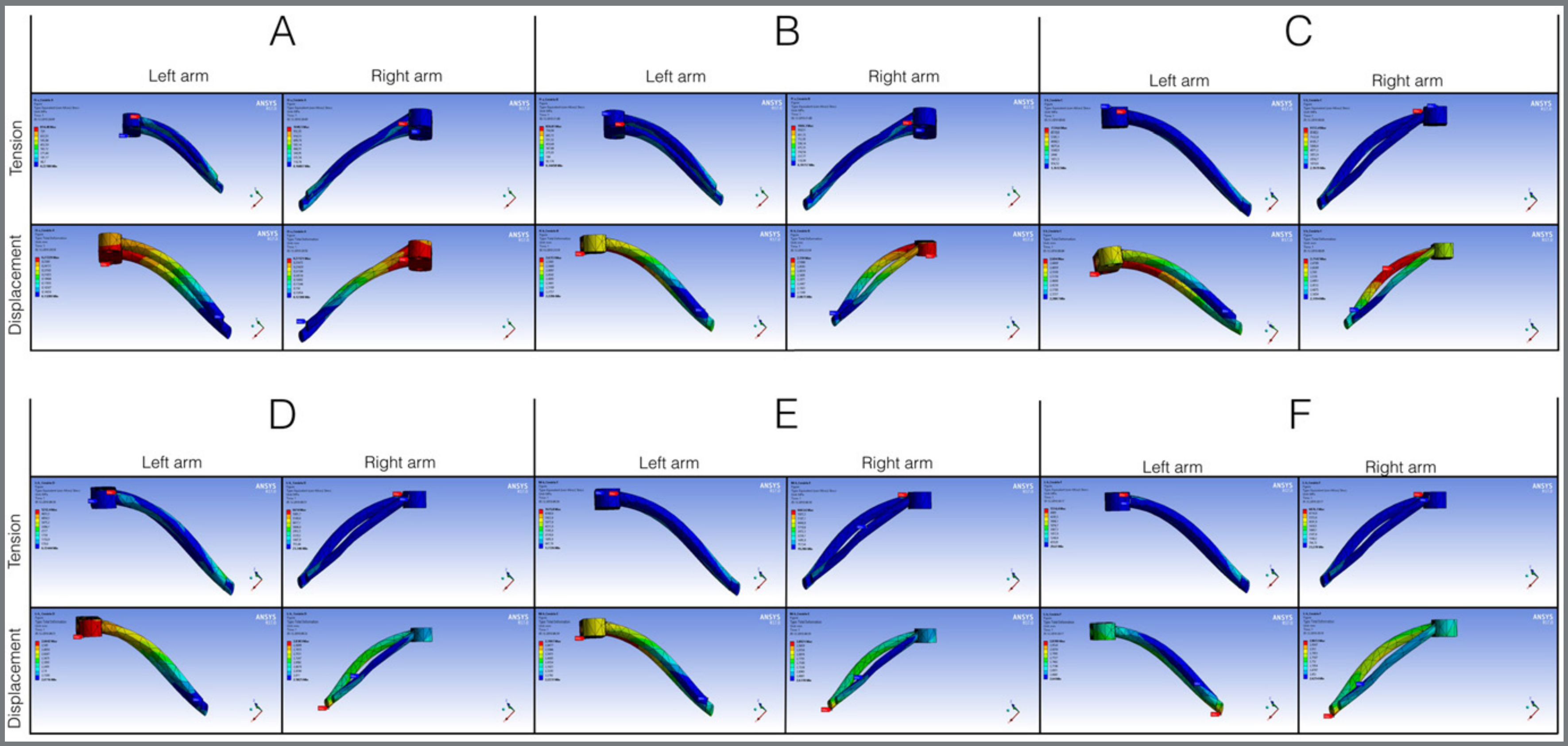

Figure 7: Distribution of tension and displacement in the arms of the expander appliance for closed midpalatal suture.

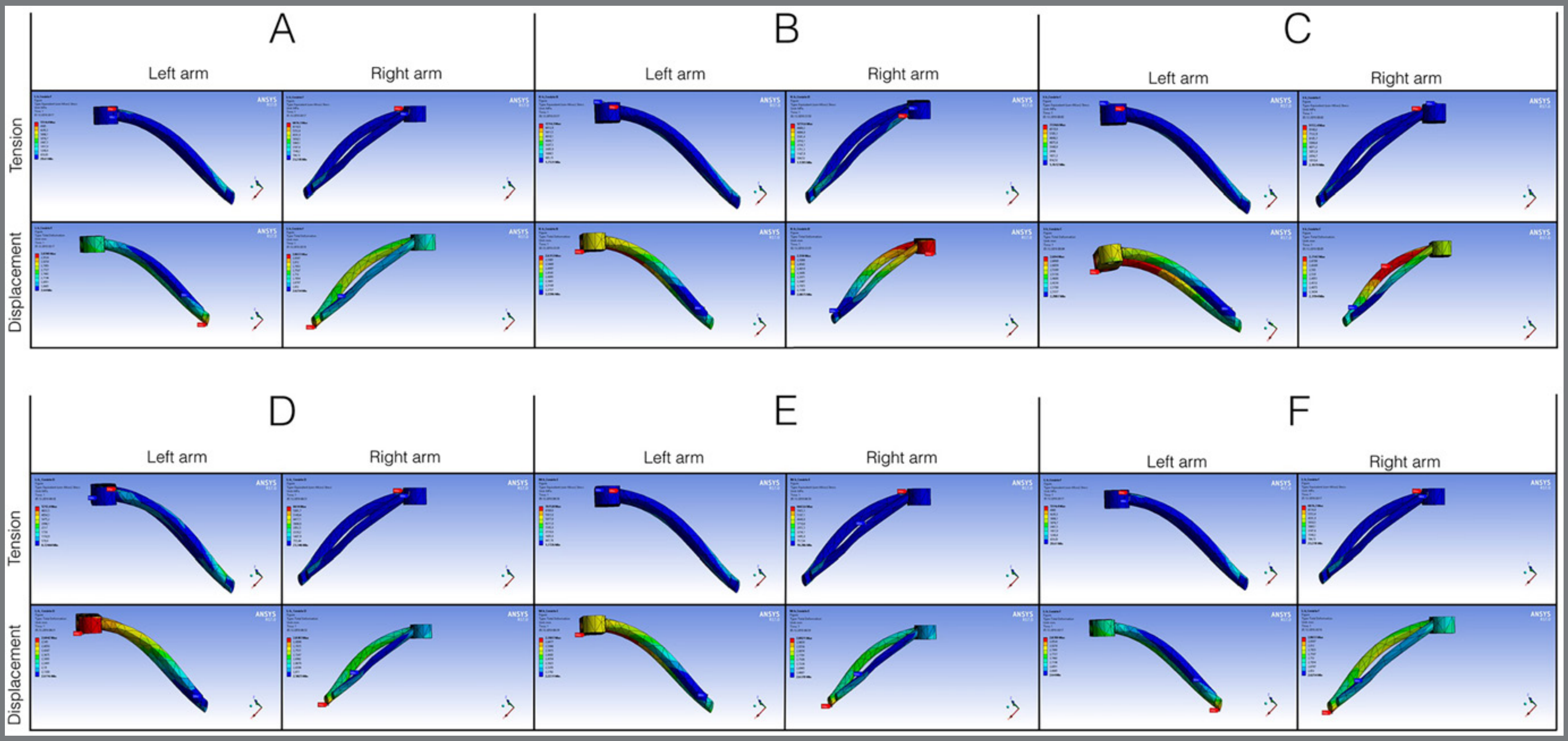

Figure 8: Distribution of tension and displacement in the arms of the expander appliance for open midpalatal suture.

DISCUSSION

From its inception to the present day, the technique of maxillary expansion supported by mini-implants has undergone modifications either by personal preferences or by the specific needs of the case regarding the number of mini-implants. It is not uncommon to find a palate that does not allow the installation of mini-implants or cases where after installation there is failure in one or more mini-implants. In view of the above, this study aimed to evaluate the stress and displacement of the mini-implants and expander appliance during rapid maxillary expansion, using FEM and varying the quantity and location of the mini-implants.

The mini-implants of the open suture simulation had the highest tensions and displacements when compared to those in the closed suture, despite offering no initial resistance in the medial palatine region. This suggests that the craniofacial bone structure offers important resistance to the displacement applied in the appliance besides, of course, the greater displacement employed. In fact, the variations observed in the forces dissipated by the expander appliance are directly related to the greater or smaller degree of resistance of the craniofacial structures.[6] Although the mini-implants with the closed palatine suture showed the lowest stress values, the value found is still important, considering the displacement of only 0.5 mm that was performed for the simulation prior to rupture of the suture.

A rapid expansion with two mini-implants for anchorage is preferentially applied in adolescents and in cases of probable lower resistance of the sutures,[7,8] due to the expansion method with four mini-implants supposedly causing opening difficulty to young adults.[1-5] The configuration with four mini-implants in the simulations with open suture showed lower maximum stress values than the configurations with two mini-implants (Table 4, columns A, B, C and F), reinforcing the indication of four mini-implants for MARPE and reserving two mini-implants for cases where the sutures offer less resistance. In the closed suture simulation, similar values were observed in the configurations with two and four mini-implants (Table 2, columns A, B, C, F), probably because the activation displacement was only of 0.5 mm. Additionally, a previous FEM study identified that, in terms of stress distribution and transverse displacement, four mini-implants are preferable.[17]

Deformation of the MARPE anchorage mini-implants was associated with the distance of the force applied to the cortical/mini-implant interface; that is, the further away from the palate the expander appliance, the greater the likelihood of deformation.[1] Simulations with three mini-implants (Tables 2 and 4, columns D and E) represent the clinical scenario of failure of some mini-implants. Greater stress was observed in the isolated mini-implants, in relation to the symmetrical simulations with two or four mini-implants, indicating that they are appliances with greater overload and the possibility of deformation of the anchorage.

Given the clinical possibility of anchorage failure, the adoption of bicortical anchorage is mandatory for the procedure.[12,18] However, in the case of mini-implant failure, to avoid stress overload in the isolated mini-implant (Table 2 – D and E), it may be necessary to reposition the MARPE in a new location.

Rapid expansion with dental anchoring presents as disadvantages sloping of the anchoring teeth and a reduction in the vestibular alveolar bone crest.[19,20] The incorporation of mini-implants in expander appliances may contribute to forcing delivery to the sutures and a decrease in excessive stress on the buccal plate.[21] MARPE has the advantage of minimizing these side effects, although the procedure has been questioned in terms of real preservation of the side effects in the molars.[22,22] In a clinical study with anchorage of only two mini-implants, a reduction in the buccal cortical surface was observed.[23] It is possible that the design of the appliance, the quality of the steel and welding, the dimensions of the mini-implants involved, the mono- or bicortical anchorage, the quantity of expansion activations, the age of the patient and the degree of maturation of the midpalatal suture influence reduction of the buccal cortical surface and undesirable vestibular inclination of the molars. In the present study, simulating anchorage with up to four mini-implants, it was observed that the arms of the expander appliance presented stress and displacement in the region near the molar in all groups (Figs 7 and 8), indicating possible side effects, even if of lower intensity.

In this study, the FEM was applied, which generated an approximate computational number of the stress and displacements according to the simulations. It is a method that presents advantages over other research methodologies, to answer the test question, especially for the feasibility of development. However, in the same context it is evaluated as a complementary method of study, and it needs support for its validation of results, with new simulations by FEM or other existing research methodologies. The results obtained here may differ from clinical results because several factors interfere biomechanically in MARPE, such as suture maturity, bone density, biological considerations and anatomy of the palate and adjacent structures.[24] Therefore, the simulations in this research do not represent all possible clinical situations, and we suggest new computational or mechanical studies to confirm the results.

CONCLUSION

The results of the FEM simulation indicate that:

1. The arms of the expander appliance presented stress and displacement in the region near the molar.
2. In the scenarios with three mini-implants, the mini-implant isolated on one side received tension overload.
3. The displacements of the mini-implants and arms of the appliance were similar in all tests.

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

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Do dental bleaching sessions prior to orthodontic treatment change the bond strength of esthetic brackets?

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ABSTRACT

Objective: The aim of this experimental *in vitro* study was to evaluate whether dental bleaching performed before orthodontic treatment change the shear bond strength (SBS) of monocrystalline and polycrystalline esthetic brackets.

Methods: Sixty (60) bovine incisors teeth were used and randomly divided into the following six groups (n=10): SCP (without bleaching/polycrystalline brackets); SCM (without bleaching/monocrystalline brackets); 1CP (one bleaching session/polycrystalline brackets); 1CM (one bleaching session/monocrystalline brackets); 3CP (three bleaching sessions/polycrystalline brackets); and 3CM (three bleaching sessions/monocrystalline brackets). The brackets were bonded seven days after the bleaching sessions. The samples were submitted to the SBS test in a universal testing machine (Instron model 4411) at 1 mm/min crosshead speed. The two-way analysis of variance (ANOVA) and the Tukey tests were performed at a 5% level of significance. After the mechanical test, samples were evaluated to determine the adhesive remnant index (ARI).

Results: The SBS values were significantly higher for the monocrystalline brackets, when compared with the polycrystalline type ($p < 0.0001$), and significantly higher with three bleaching sessions than without bleaching ($p < 0.0436$). The ARI showed predominance of failures between the bracket and resin for all the groups (score 3).

Conclusion: Three dental bleaching sessions increased the SBS values. Monocrystalline brackets showed higher SBS values than the polycrystalline type.

Keywords: Orthodontic brackets. Teeth bleaching. Orthodontics. Shear strength.

RESUMO

Objetivo: O objetivo do presente estudo experimental *in vitro* foi avaliar se sessões de clareamento dental antes do tratamento ortodôntico alteram a resistência da união ao cisalhamento (RUC) de braquetes estéticos dos tipos monocristalino e policristalino. **Métodos:** Sessenta (60) dentes incisivos bovinos foram utilizados e divididos aleatoriamente nos seguintes seis grupos (n = 10): SCP (sem clareamento/braquetes policristalinos); SCM (sem clareamento/braquetes monocristalinos); 1CP (uma sessão de clareamento/braquetes policristalinos); 1CM (uma sessão de clareamento/braquetes monocristalinos); 3CP (três sessões de clareamento/braquetes policristalinos); e 3CM (três sessões de clareamento/braquetes monocristalinos). Os braquetes foram colados sete dias após as sessões de clareamento. As amostras foram submetidas ao teste de RUC em máquina universal de ensaios (Instron modelo 4411) na velocidade de 1 mm/min. Foi realizada análise de variância de dois fatores (ANOVA) e teste de Tukey, com nível de significância de 5%. Após o ensaio mecânico, as amostras foram avaliadas para determinação do índice de adesivo remanescente (ARI), de acordo com o método proposto por Artun e Bergland, com o auxílio de uma lupa com lente de aumento de 25x. **Resultados:** Os valores de RUC foram significativamente maiores para os braquetes monocristalinos do que para os policristalinos ($p < 0{,}0001$) e significativamente maiores com três sessões de clareamento do que sem clareamento ($p < 0{,}0436$). O ARI mostrou predomínio de falhas entre o braquete e a resina para todos os grupos (escore 3). **Conclusão:** Três sessões de clareamento dental têm efeito positivo na RUC. Os braquetes monocristalinos apresentaram valores de RUC superiores aos do tipo policristalino.

Palavras-chave: Braquetes ortodônticos. Clareamento dental. Ortodontia. Resistência ao cisalhamento.

INTRODUCTION

Dental bleaching is an easy and conservative therapy for whiting teeth.[1,2] Dental bleaching can be performed at-home or in-office,[3-5] and the most common used substances are carbamide and hydrogen peroxide in various concentrations.[3,4]

Patients willing to have white and aligned teeth have associated dental bleaching with orthodontic treatment,[6] undergoing the procedure before or after orthodontic treatment.[7]

Adhesive used for bracket bonding may undergo degradation or solubility due to the presence of bleaching agents.[8] Various methods have been proposed to avoid problems related to reduction in bond strength after bleaching, such as application of antioxidant, desensitizing agents,[2,4] sodium ascorbate, tocopherol acetate, retinol acetate,[9] or increase post-bleaching time interval for bracket bonding.[1,5,8]

Patients who are concerned about esthetics during orthodontic treatment have the option of using monocrystalline or polycrystalline esthetic brackets.[10] Both types are composed of aluminum oxide,[11,12] with different manufacturing process. Polycrystalline ceramic brackets are composed of polycrystalline alumina, made up of aluminum oxide crystals fused at high temperatures, allowing various brackets to be molded simultaneously.

Polycrystalline brackets are more common and popular, due to the quality of the material and the relative ease of production. In turn, monocrystalline ceramic brackets consist of a mass cast at a high temperature (2,100ºC) forming a single aluminum oxide crystal that will result in the fabrication of a single bracket, thus making the production process more expensive. However, this form of milling presents lower incorporation of impurities, making the brackets stronger and more translucent. This difference may favor the transmission of light and influence the polymerization of the resin used for bonding the brackets, therefore generating an influence on the shear bond strength (SBS).[13]

Concern is related to the SBS of brackets bonded after bleaching procedures,[6-9,14] and few studies have compared the retention of different types of esthetic brackets used nowadays. Based on the literature, studies of SBS after bleaching treatments refer to a single session of dental bleaching.[1-4,6,8,9,15] In an endeavor to approximate clinical reality, in which the dentist commonly performs more bleaching sessions, the proposal of the present study was to test the following hypothesis: 1) the number of bleaching sessions performed prior to esthetic bracket bonding may influence the SBS, bearing in mind that bleaching sessions may change the enamel surface, thereby reducing the bond strength; 2) the type of esthetic bracket (monocrystalline or polycrystalline) may influence the SBS. Therefore, the aim was to evaluate, *in vitro*, the SBS of esthetic brackets (monocrystalline or polycrystalline) after one and three dental bleaching sessions.

MATERIAL AND METHODS

The present experimental *in vitro* study was approved by the Research Ethics Committee (number 596/2018, *Fundação Hermínio Ometto*). Sixty (60) bovine incisors teeth without fractures, cracks or white stain lesions were used. Freshly extracted teeth without any previous chemical substance treatment were selected for testing. The teeth were cleaned with a periodontal curette, then rinsed and stored in distilled water at room temperature of 37°C[4]. The specimens were thus inserted into PVC tubes and fixed with acrylic resin (JET, São Paulo, SP, Brazil). Teeth were manually positioned so that the vestibular surfaces were set perpendicular to the ground with the aid of an acrylic plate. After the resin cure, prophylaxis of the specimen was performed with a pumice stone and water, with the aid of a Robinson brush, and subsequently the specimens were stored at room temperature.

The specimens were randomly divided into six groups (n = 10). Polycrystalline Roth brackets (Iceram, Orthometric, Marília, São Paulo, Brazil) and monocrystalline Roth brackets (Iceram S, Orthometric, Marília, São Paulo, Brazil) were used.

Groups 1CP and 1CM received dental bleaching, prior to bracket bonding, with 37% carbamide peroxide gel (Office power bleaching 37%, BM4, Palhoça, Santa Catarina, Brazil), for 45 minutes, in accordance with the manufacturer's instructions. After bleaching, teeth were washed with water/air for 30 seconds and stored at room temperature. Polycrystalline brackets were bonded to Group 1CP; and monocrystalline brackets, to Group 1CM, seven days after the bleaching session.

Groups 3CP and 3CM received dental bleaching in the same way as was performed in Groups 1CP and 1CM; however, three bleaching sessions were performed with a time interval of seven days between each session. Polycrystalline brackets were bonded to Group 3CP; and monocrystalline brackets, to Group 3CM, seven days after the last bleaching session.

For bracket bonding, 37% phosphoric acid (Condac, FGM, Joinville, Santa Catarina, Brazil) was applied for 15 seconds, followed by washing with water jet for 30 seconds and drying with air jet for 15 seconds. Subsequently, Transbond XT Primer adhesive (3M Unitek, Monrovia, USA) was applied on the tooth surface and polymerized for 15 seconds. Transbond XT was applied at the straight wire incisor bracket base (Orthometric). The brackets were manually placed on the tooth surface and the excess was removed with an exploratory probe. Polymerization was performed for 10 seconds on each surface (distal, mesial, cervical and occlusal) with an Optilight Max 440 light polymerization device (Gnatus®, wavelength 420 to 480 nm, irradiance 1200 mV/cm^2) and stored at room temperature until the tests were performed. The brackets were submitted to the SBS test in a universal test machine (Model 4411; Instron Inc., Canton, MA, USA) at a compressive speed of 1 mm/min. The maximum debonding force was divided by the area of the brackets base, and the results were reported in megapascal (MPa). A descriptive analysis of data was performed, and the results were presented as mean and standard deviation. The normality and homoscedasticity of the data were assessed. The results were submitted to two-way analysis of variance, and if difference was observed between the groups, the complementary Tukey's test was performed ($p < 0.05$).

After the SBS test, the adhesive remnant Index (ARI) was evaluated with the aid of a magnifying glass, with 25x magnification lens, in accordance with the method proposed by Artun and Bergland[16]. Scores ranged from 0 to 3:

0 - Absence of any adhesive remnant layer on the enamel.

1 - Presence of less than half of the resin remnant on the enamel.

2 - Presence of more than half of the resin remnant on the enamel.

3 - Presence of all the resin on the enamel, together with the impression of the bracket base mesh.

RESULTS

Table 1 shows that the bond strength was significantly higher for the monocrystalline brackets (54.22 ±13.15 MPa) than for the polycrystalline type (20.28 ±11.23 MPa) ($p < 0.0001$). Regardless of the type of bracket, the bond strength was significantly higher with three bleaching sessions (40.30±17.96 MPa) when compared to the control group (32.08±20.93 MPa) ($p < 0.0436$).

Evaluation of the ARI demonstrated predominance of score 3 (58/60 – 96,7%), except for Groups 1CP and 1CM, in which one of the test specimens presented a score 2 (2/60 – 3,3%) (Table 2).

Table 1: Mean shear bond strength (MPa) and standard deviation, considering number of bleaching sessions and type of esthetic bracket.

Treatment	Brackets		Tukey
	Polycrystalline	Monocrystalline	
Without bleaching	14.37 (7.80)	49.79 (12.90)	$(32.08\pm20.93)^{b}$
1 bleaching session	20.04 (10.51)	58.71 (15.70)	$(39.38\pm23.72)^{ab}$
3 bleaching sessions	26.44 (12.40)	54.16 (10.01)	$(40.30\pm17.96)^{a}$
Tukey	$(20.28 \pm11.23)^{B}$	$(54.22 \pm13.15)^{A}$	-

Groups with different superscript letters (capital letters comparing on the horizontal line and lower cases in the vertical differed among them ($p \leq 0.05$). p (bracket) < 0.0001; p (treatment) = 0.0436; p (bracket x treatment) = 0.2346.

Table 2: Adhesive Remnant Index of monocrystalline and polycrystalline brackets submitted to 1 and 3 bleaching sessions.

	SCP	SCM	1CP	1CM	3CP	3CM	Total
0	0%	0%	0%	0%	0%	0%	0%
1	0%	0%	0%	0%	0%	0%	0%
2	0%	0%	10% (1)	10% (1)	0%	0%	3.3% (2)
3	100% (10)	100% (10)	90% (9)	90% (9)	100% (10)	100% (10)	96.7% (58)
Total	100% (10)	100% (10)	100% (10)	100% (10)	100% (10)	100% (10)	100% (60)

SCP: without bleaching/polycrystalline brackets; SCM: without bleaching/monocrystalline brackets; 1CP: one bleaching session/polycrystalline brackets; 1CM: one bleaching session/monocrystalline brackets; 3CP: three bleaching sessions/polycrystalline brackets; 3CM: three bleaching sessions/monocrystalline brackets.

DISCUSSION

The initial hypothesis of this study, that one and three in-office bleaching sessions would reduce the bond strength, was rejected (1); the hypothesis that the type of bracket, monocrystalline or polycrystalline, would influence the SBS was accepted (2).

The present results demonstrated that three bleaching sessions increased the SBS of both types of brackets (monocrystalline and polycrystalline), corroborating the findings of other studies that verified higher SBS in previously bleached groups, when compared to without previous bleaching.[4,9] On the other hand, the study of Andrighetto et al.[2] observed no differences in the SBS values in brackets bonded after bleaching or not bleached. Moreover, it was also possible to find reports contradicting the present findings, in which the SBS of brackets was higher in the groups without bleaching prior to bracket bonding.[1,3,15]

It is believed that the differences in the present results, when compared with the literature, was due to the methodological differences, because studies normally compare the group without bleaching and groups submitted to a single dental bleaching session. However, the present research intended to approximate the clinical reality, in which in-office dental bleaching is commonly performed in more than one session, to attain the expected result. Previous studies that compared the surface roughness after dental bleaching have suggested that bleaching promoted changes in the superficial layers of enamel.[17-20] Roughness then justified the SBS increase in the groups exposed to three bleaching sessions, suggesting that more bleaching sessions promoted irregularities in the enamel, thus increasing the mechanical retention of resin on the tooth surface.

When the types of esthetic brackets (monocrystalline and polycrystalline) used in this study were compared, regardless of the condition, the monocrystalline brackets showed higher SBS values. Corroborating these findings, other studies have also observed higher SBS values in monocrystalline brackets, when compared to polycrystalline.[21,22] On the other hand, other researches have found no significant differences between monocrystalline and polycrystalline esthetic brackets.[12,23] The higher SBS values found in the monocrystalline brackets, when compared with the polycrystalline type, may be explained by their composition and manufacturing process, because they have less incorporation of impurities, which makes the bracket more translucent, allowing the bracket to retain less light, directly interfering in the efficiency of resin polymerization, thereby increasing retention to the tooth.[11,13,22,23]

Regarding ARI, score 3 was predominant in the evaluated groups. Ten percent of the sample in Groups 1CP and 1CM presented score 2. Bleaching prior to bracket bonding did not interfere in the ARI, demonstrating high effectiveness of the selected resin for bracket bonding purpose. The present results corroborate the findings of previous studies.[12,21-23] This finding is advantageous, because the ideal is to remain all the material on the tooth surface, thus protecting the enamel.[24,25]

Finally, the authors suggest that new clinical studies should be carried out with the objective of evaluating the long-term retention of esthetic brackets after dental bleaching, since the results of this study express an *in vitro* setting.

CONCLUSION

After three sessions, dental bleaching increased shear strength of aesthetic brackets. The monocrystalline brackets presented the highest SBS values.

AUTHORS CONTRIBUTIONS

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SGP, DPAC, PRS, ABC, SASV, HCV.

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SGP, DPAC, PRS

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Overall responsibility:
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ORIGINAL ARTICLE

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Effect of second molar eruption on efficiency of maxillary first molar distalization using Carriere distalizer appliance

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ABSTRACT

Introduction: Maxillary molar distalization is a common approach for correcting dental Class II malocclusions.

Objective: This study aimed at comparing the outcomes of maxillary first molar distalization using the Carriere appliance before and after second molar eruption.

Methods: Two groups of patients with dental Class II malocclusions were treated with Carriere distalizer appliance with heavy rectangular mandibular wire and lingual arch for anchorage. Patients of the first group presented unerupted maxillary second molars during the distalization period. In the second group, maxillary second molars were in occlusion on treatment onset. Cone beam computed tomography images were taken at the beginning of treatment and after finishing molar distalization, to compare both groups regarding first molar distalization, intrusion, mesiodistal tipping, buccolingual torquing and rotation, anchorage loss and skeletal changes. Also, the treatment durations were compared.

Results: The mean first molar distalization period in the first group (19.2 ± 1.6 weeks) was significantly smaller than the second group (23.3 ± 2.3 weeks). The amount of maxillary first molar distalization was significantly greater, while the amount of rotation was significantly smaller in the first group. No statistically significant differences in the amounts of maxillary first molar intrusion, mesiodistal tipping and buccolingual torquing between both groups was found. Mandibular incisor labiolingual torquing and mandibular first molar mesialization and mesiodistal tipping were significantly greater in the second group.

Conclusions: Maxillary first molar distalization before maxillary second molar eruption is more efficient, with less anchorage loss than after second molar eruption.

Keywords: Maxillary molar distalization. Carriere distalizer. Second molar eruption.

RESUMO

Introdução: A distalização do molar superior é uma abordagem comum para a correção da má oclusão de Classe II dentária.

Objetivo: O presente estudo teve como objetivo comparar os resultados da distalização do primeiro molar superior usando o aparelho Carriere antes ou após a erupção do segundo molar.

Métodos: Dois grupos de pacientes com má oclusão de Classe II dentária foram tratados com o distalizador Carriere, com arco inferior retangular espesso e um arco lingual para ancoragem. Os pacientes do primeiro grupo não apresentavam os segundos molares irrompidos durante o período de distalização. No segundo grupo, os segundos molares superiores estavam em oclusão no início do tratamento. Imagens de tomografia computadorizada de feixe cônico foram obtidas no começo do tratamento e após o término da distalização do molar, para comparar ambos os grupos quanto à distalização, intrusão, inclinação mesiodistal, torque vestibulolingual e rotação do primeiro molar, além da perda de ancoragem e mudanças esqueléticas. O tempo de tratamento de ambos os grupos também foi comparado.

Resultados: O tempo médio de distalização do primeiro molar no primeiro grupo (19,2 ± 1,6 semanas) foi significativamente menor que no segundo grupo (23,3 ± 2,3 semanas). A quantidade de distalização do primeiro molar superior foi significativamente maior e a quantidade de rotação foi significativamente menor no primeiro grupo. Não foram encontradas diferenças significativas entre ambos os grupos quanto à quantidade de intrusão, inclinação mesiodistal e torque vestibulolingual do primeiro molar. O torque vestibulolingual nos incisivos inferiores e a mesialização e inclinação mesiodistal do primeiro molar inferior foram significativamente maiores no segundo grupo.

Conclusões: A distalização do primeiro molar superior feita previamente à erupção do segundo molar superior é mais eficiente, apresentando menor perda de ancoragem do que quando realizada após a erupção do segundo molar.

Palavras-chave: Distalização do molar superior. Distalizador Carriere. Erupção do segundo molar.

INTRODUCTION

Dental Class II molar relationship is a frequent malocclusion that can be successfully resolved by means of extractions in at least one arch,[1,2] using intermaxillary elastics[2,3] or maxillary molar distalization.[4-6] Molar distalization has become more prevalent because Class I molar relationship is achieved, a certain amount of space is gained, and tooth extractions can be prevented.[6]

Different types of appliances can be used to distalize maxillary molars including pendulum,[4] distal jet,[5] headgear[7] and miniscrews.[8] The Carriere distalizer (Henry Schein Inc., New York, NY) is a simple fixed appliance used for nonextraction Class II correction, by moving the Class II buccal segment as a block unit into a Class I occlusion.[9] It was designed to use anchorage from the mandibular arch to create Class I molar and canine relationships.[9,10]

The distalization phase with the Carriere distalizer appliance commonly precedes full Edgewise appliances bonding, thus increasing adolescent patient's comfort and general experience.[11,12] The following fixed appliance therapy may be combined with orthodontic or orthopedic maxillary expansion, to refine and detail the occlusion.[12]

The type of first molar movement and the treatment timing (before or after second molar eruption) are two factors affecting not only the success, but also the efficiency of molar distalization.[13]

An unerupted maxillary second molar can perform as a fulcrum, resulting in much more evident first molar tipping than when both molars are distalized together. Accordingly, the eruption level of the second molar can have an essential influence on the first molar distalization.[14]

On the contrary, distalization of maxillary first molar alone can result in greater amount of distalization, higher movement rate and less anchorage loss than when both first and second molars are distalized concurrently.[15] The treatment duration for maxillary first molar distalization increases if the second molar is erupted.[16,17] Accordingly, the ideal age for maxillary first molar distalization is supposed to be prior to second molar eruption.[15-17]

Other studies concluded that the change of the first molar position and the amount of anchorage preservation are not changed significantly whether the second molar is erupted or not.[4,18,19] The belief that the unerupted second molar represents a fulcrum, increasing the distal tipping of the distalized first molar, is unsupported.[13]

Most of the previous studies explaining the effect of maxillary second molar eruption on maxillary first molar distalization used distalizers depending on the upper arch for anchorage, and relied on two-dimensional lateral cephalometric radiographs.[13,14,17,19] Shortcomings of these two-dimensional radiographs included magnification, geometric distortion, superimposition of anatomical structures and inconsistent head position.[20] There were no studies, to the best of our knowledge, that used cone beam computed tomography (CBCT) to compare maxillary first molar distalization with Carriere distalizer appliance before and after second molar eruption.

Using CBCT to measure various skeletal and dental changes in the present study could offer the distinct advantage of one-to-one geometry, and provide the potential for utilizing additional anatomical landmarks not detectable in the two-dimensional cephalograms.[21,22] Moreover, distinct views could be obtained for both right and left sides, allowing to increase the efficiency of image utilization, by omitting the superimposition of structures that were unrelated to the required landmark determination, and three-dimensional measurements.[22] The multi-planer reconstruction displays of CBCT views can offer more accurate determination of cephalometric landmarks than conventional lateral cephalograms.[23]

Accordingly, the aim of this study was to compare the outcomes of maxillary first molar distalization using the Carriere distalizer appliance before and after second molar eruption. The null hypothesis was that the results of maxillary first molar distalization — including three-dimensional maxillary first molar movements, anchorage loss, amount of Class II correction and treatment duration — were not affected whether maxillary second molar was erupted or not.

MATERIAL AND METHODS

This prospective study included two groups of patients indicated for maxillary first molar distalization (thirty patients for each group). In the first group (19 females and 11 males, mean age of 11.6± 0.9 years), the treatment was accomplished prior to the eruption of the maxillary second molar, with the follicles of the second molars placed directly toward the cervical third of the first molar root. In the second group (21 females and 9 males, mean age of 14.3 ± 1.4 years), distalization started when both maxillary first and second molars erupted.

Patients in both groups fulfilled the following inclusion criteria:

1. More than half-cusp bilateral Angle's Class II molar relation.
2. Skeletal Class I malocclusion, with ANB angle less than 4° and YEN angle between 117° and 123°.[24, 25]

3. Total mandibular arch discrepancy, indicating that there was no need for extraction in the mandibular arch.
4. No pretreatment transverse discrepancy.
5. No previous orthodontic treatment.

The sample size was calculated according to the following formula:

$$n= \frac{2\left(Z_{\propto}+Z_{[1-\beta]}\right)^{2}\times\left(\frac{SD_1{}^2+SD_2{}^2}{2}\right)}{D^2}$$

In which Z_α = 1.96 for α of 0.05 (significance at $p < 0.05$) and $Z_{[1-\beta]}$ = 1.28 for β of 0.10 (the power of study is 90%). Also, SD_1 and SD_2 are the standard deviations of maxillary molar distalization for a pilot study of ten randomly selected patients in the first and the second groups, respectively. D is the effect size (the minimal clinical relevant maxillary molar distalization difference between both groups in the pilot study).

$$\text{So, } n= \frac{2\,(1.96+1.28)^2\times\left(\frac{0.97^2+1.19^2}{2}\right)}{(0.91)^2}$$

n= 30 patients per group.

Distalization was performed with the Carriere distalizer appliance for all patients (Figs 1 and 2). A 0.036-in lower lingual holding arch was soldered to bands cemented on the mandibular first molars, to provide anchorage for molar distalization. The mandibular arch was bonded for all patients by the same operator, using mini master brackets with 0.022-in slot size (American Orthodontics, Sheboygan, Wis) and leveled reaching 0.019 × 0.025-in stainless steel archwire. The distalizer was then bilaterally bonded by the same operator in all subjects.

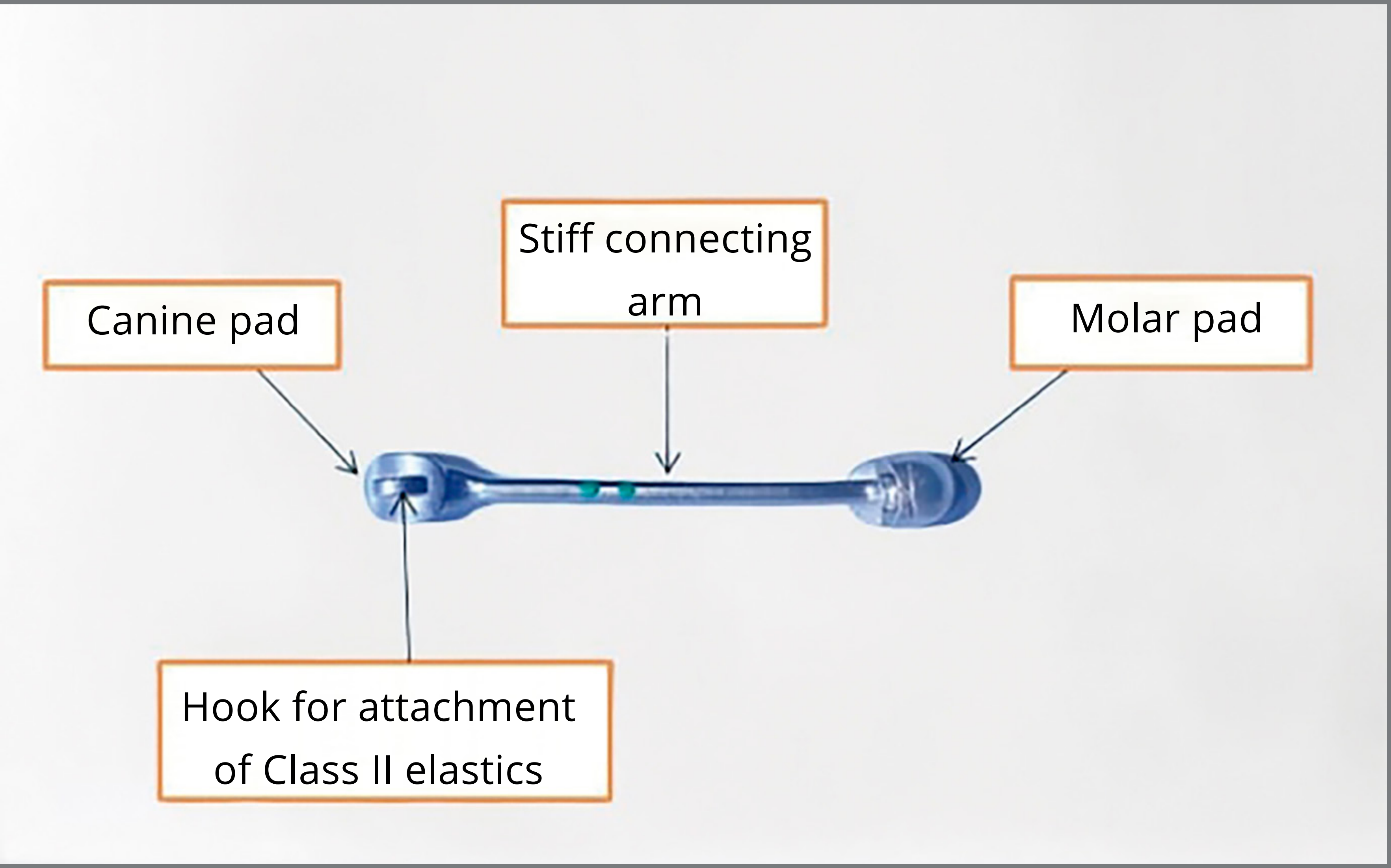

Figure 1: Design of the Carriere distalizer.

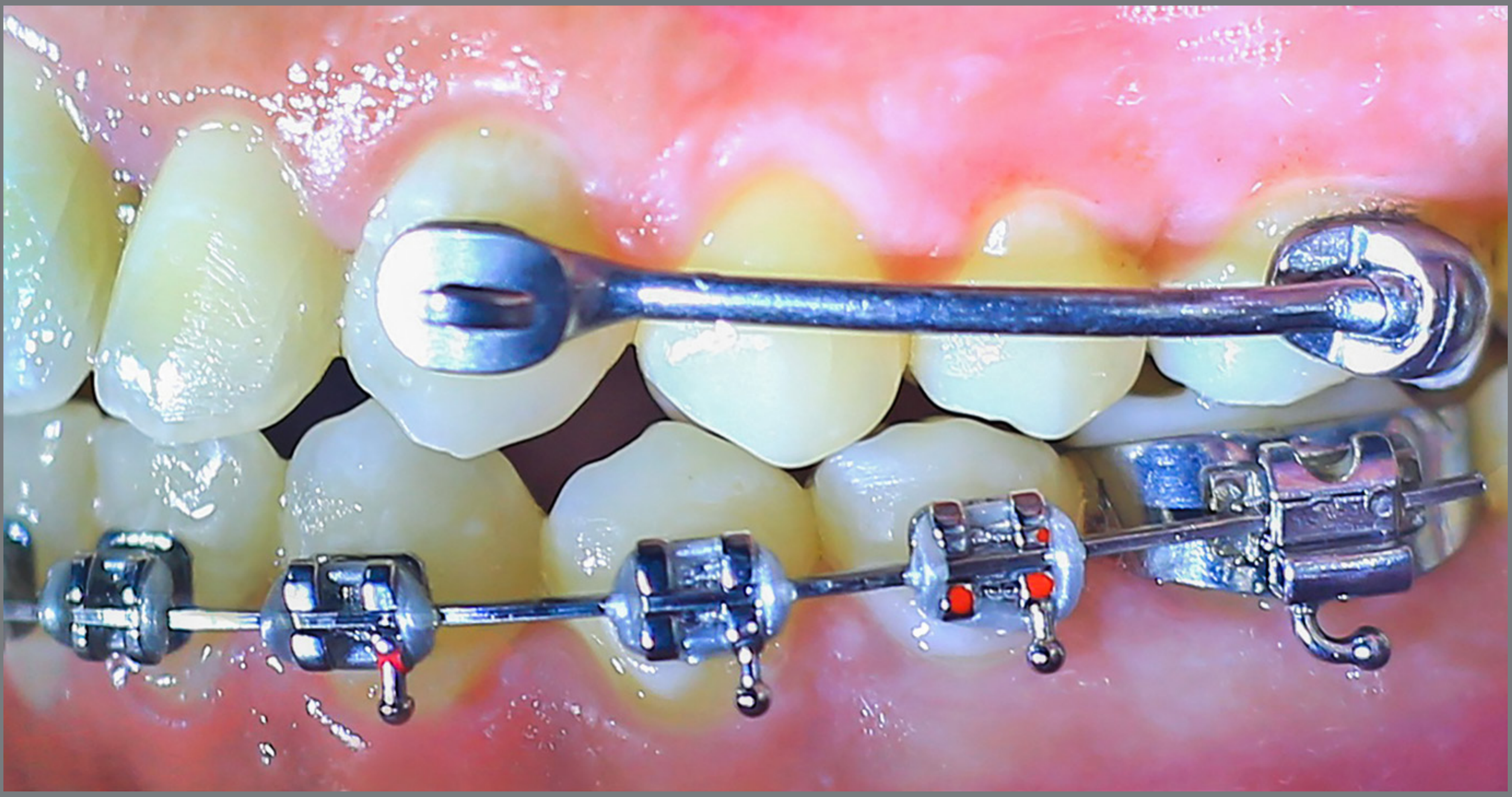

Figure 2: Bonded Carriere distalizer appliance.

All patients were instructed to use heavy Class II elastics with 1/4-in diameter (American Orthodontics, Sheboygan, Wis), attaching them from the mandibular molar band hook to the hook on maxillary cuspid pad of the distalizer. A force gauge (Dentaurum, Pforzheim, Germany) was used to measure the amount of force produced by Class II elastics once attached. Patients were instructed to wear the elastics all the time, except during eating or playing sports, and to change them after every meal.

Every patient was instructed to fill-in a schedule, for self-reporting the duration of wearing Class II elastics every day. Follow-up visits were scheduled every two weeks, to report any problems and to check the compliance of the patients. Reports from parents were required to overcome the social desirability bias during filling-in the schedule. Patients were also instructed to fill in the report every hour, helped by memory aids to overcome the recall bias.[26]

One CBCT image (Scanora3D, Sorredex- Finland) was taken for each patient before distalization, and another one when a bilateral Class I molar relationship was attained, in the same standardized technique. Exposure was performed at 15 mA and 85 KV. The obtained CBCT images were transformed to DICOM format (Digital Imaging and Communications in Medicine) with the i-CAT software (Hatfield, Pennsylvania, USA). A fully reconstructed three-dimensional volumetric image was generated by utilizing the Mimics image processing software (Materialise Group, Leuven, Belgium).

The three-dimensional images were subsequently reoriented to the Frankfort horizontal reference plane. The sagittal reference plane was set perpendicular to the horizontal reference plane, and connecting the nasion and the right porion points. The frontal plane was extended from the nasion, and normal to the horizontal and sagittal planes. Identification of landmarks was determined by using the generated multiplanar projections. The selected points were then assessed in the three-dimensional image. Measurements were taken to compare both groups regarding the amounts of maxillary first molar distalization, mesiodistal tipping, bucccolingual torquing and rotation, in addition to anchorage loss and skeletal changes. Moreover, the treatment durations were compared. Figure 3 and Tables 1, 2 and 3 show the landmarks, planes and measurements used in this study.

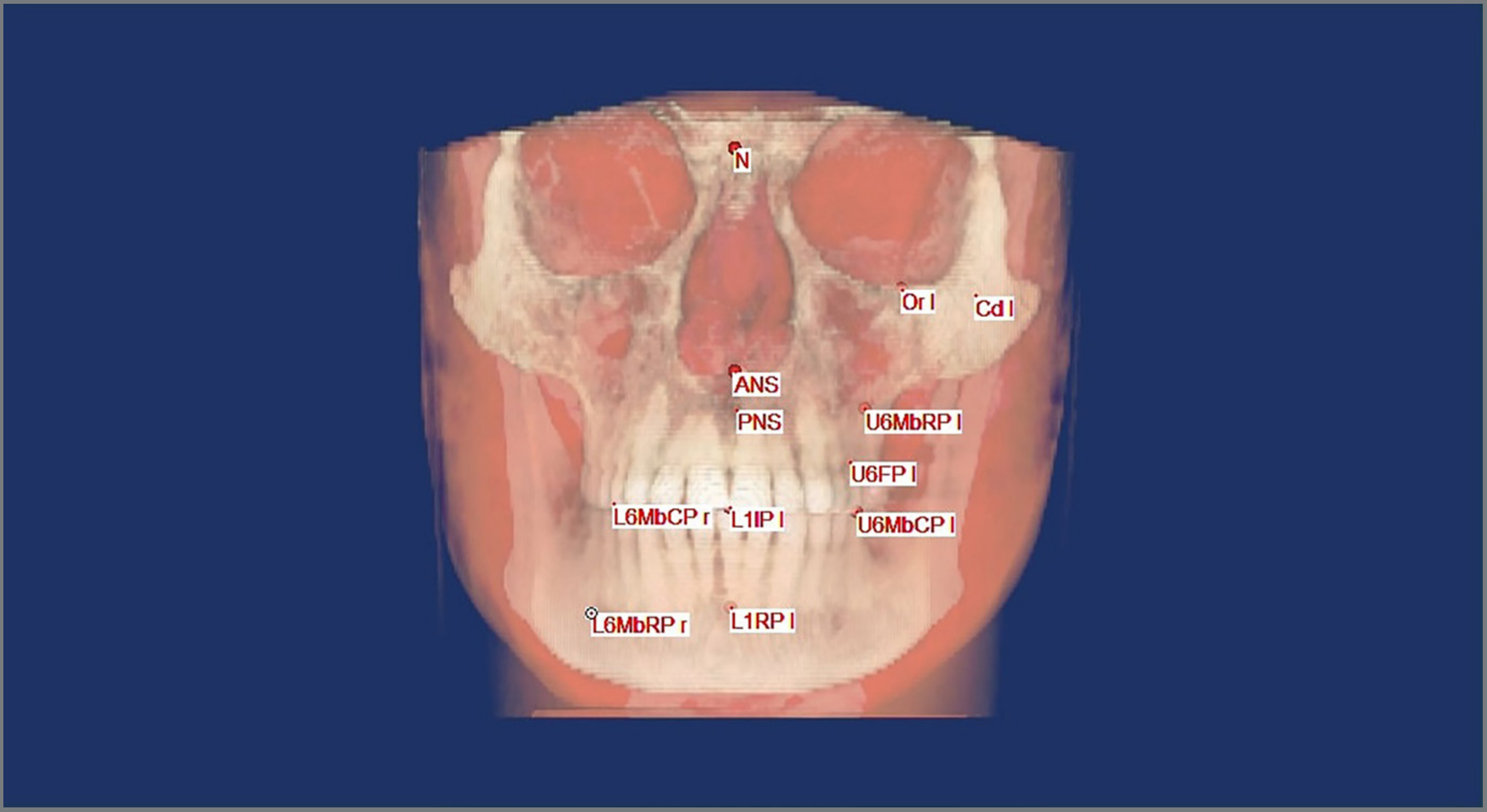

Figure 3: Determination of landmarks on the Mimics software.

Table 1: Three-dimensional cephalometric reference landmarks.

Point	Description
S (Sella)	The midpoint of the sella turcica
N (Nasion)	The most anterior point on the frontonasal suture
A (Subspinale)	The deepest midline point in the curved bony outline from the base to the alveolar process of the maxilla
B (Supramentale)	The most posterior point in the outer contour of the mandibular alveolar process in the median plane
M point	The center of the largest best fit circle tangent to anterior, superior, and palatal surface of premaxilla (midpoint of the premaxilla)
G point	The center of the largest best fit circle tangent to the internal, anterior, inferior, and posterior surfaces of mandibular symphysis (center of mandibular symphysis)
GnR (right gnathion)	The point in the midway between the most anterior and the most inferior points of the chin on the right side
OrR – OrL (right and left orbitale)	The most inferior point on the orbital margin at both sides
PoR (right porion)	The highest point on the external auditory meatus on the right side
ANS (anterior nasal spine)	The most anterior midpoint of the anterior nasal spine of the maxilla
PNS (posterior nasal spine)	The most posterior midpoint of the posterior nasal spine of the palatine bone
CdR–CdL (right and left Condylion)	The most superior point on the head of the condyle at both sides
U6MbCPR – U6MbCPL (right and left maxillary first molar mesiobuccal cusp tip)	The tip of the mesiobuccal cusp of the right and left maxillary first molar crowns
U6MbRPR – U6MbRPL (right and left maxillary first molar mesiobuccal root apex)	The apex of the mesiobuccal root of the right and left maxillary first molars
U6DbCPR – U6DbCPL (right and left maxillary first molar disto-buccal cusp tip)	The tip of the distobuccal cusp of the right and left maxillary first molar crowns
L6MbCPR – L6MbCPL (right and left mandibular first molar mesiobuccal cusp tip)	The tip of the mesiobuccal cusp of the right and left mandibular first molar crowns
U6FPR – U6FPL (right and left maxillary first molar furcation point)	The mid furcation point between the roots of the right and left maxillary first molars
L6MbRPR – L6MbRPL (right and left mandibular first molar mesiobuccal root apex)	The apex of the mesiobuccal root of the right and left mandibular first molars
L1IPR – L1IPL (right and left mandibular central incisor incisal point)	The tip of the incisal edge of each mandibular central incisor
L1RPR – L1RPL (right and left mandibular central incisor root point)	The apex of the root of each mandibular central incisor

Table 2: Three-dimensional cephalometric reference lines and planes.

Line or plane	Description
FHP (Frankfurt horizontal plane)	The plane passing through OrR, OrL and PoR points
VP (Vertical plane)	The plane passing through CdR and CdL and perpendicular to the FHP
MxS (Maxillary sagittal line)	The line connecting ANS and PNS
FL (Frontal line)	The line connecting OrR and OrL
U6 long axis	The line connecting U6MbCP and U6MbRP
L6 long axis	The line connecting L6MbCP and L6MbRP
L1 long axis	The line connecting L1IP and L1RP

Table 3: Three-dimensional CBCT measurements.

Measurement	Description
SNA	The angle between SN and NA lines
CdR - ANS	The distance between the right Condylion and the anterior nasal spine
Anteroposterior position of the maxilla	SNApre – SNApost (CdR - ANS)pre – (CdR - ANS)post
SNB	The angle between SN and NB lines
CdR - GnR	The distance between the right Condylion and the right Gnathion
Anteroposterior position of the mandible	SNBpost – SNBpre (CdR - GnR)post – (CdR - GnR)pre
ANB	The difference between SNB and SNA angles
YEN angle	angle formed between SM line and MG line
Anteroposterior relationship between maxilla and mandible	ANBpre – ANBpost YEN anglepre – YEN anglepost
U6 AP (maxillary first molar antero-posterior position)	Measured as the perpendicular distance from (U6MbCPR or U6MbCPL) to the VP (Vertical plane)
Maxillary first molar distalization	U6 APPre – U6 APPost
U6 VP (maxillary first molar vertical position)	Measured as the perpendicular distance from (U6FPR or U6FPL) to the FHP (Frankfurt horizontal plane)
Maxillary first molar intrusion	U6 VPPre – U6 VPPost
U6 MD (maxillary first molar mesio-distal angulation)	Measured as the posterior angle between the U6 long axis and the MxS (Maxillary sagittal line)
U6 mesio-distal angulation change	U6 MDPre – U6 MDPost
U6 BL (maxillary first molar bucco-lingual inclination)	Measured as the external downward angle between the U6 long axis and the FL (Frontal line)
U6 bucco-lingual inclination change	U6 BLPost – U6 BLPre
U6 ROT (maxillary first molar rotation)	Measured as the internal angle between the line connecting the U6MbCP and U6DbCP and the MxS (Maxillary sagittal line)
Maxillary molar rotation	U6 ROTPre – U6 ROTPost
L6 AP (mandibular first molar antero-posterior position)	Measured as the perpendicular distance from (L6MbCPR or L6MbCPL) to the VP (Vertical plane)
Mandibular molar mesialization	L6 APPost – L6 APPre
L6 MD (mandibular first molar mesio-distal angulation)	Measured as the posterior angle between the L6 long axis and the MxS (Maxillary sagittal line)
Mandibular molar mesio-distal angulation change	L6 MDPre – L6 MDPost
L1 BL (mandibular central incisor bucco-lingual inclination)	Measured as the anterior angle between the L1 long axis and the MxS (Maxillary sagittal line)
Mandibular incisor bucco-lingual inclination change	L1 BLPost – L1 BLPre

Before starting distalization in both groups, the severity of the Class II molar relationship was measured as the horizontal distance between the mesiobuccal cusp tips of maxillary and mandibular first molars, and compared in both groups. The distance zero indicated a half-cusp Class II molar relationship. As the distance increased, the severity of Class II relationship increased. Complementarily, the skeletal relationship was compared between both groups. Independent *t*-test revealed no significant differences between both groups in all these pretreatment variables (pretreatment Class II severity was 2.5 ± 0.8 mm and 2.2 ± 0.9 mm, respectively, with *p*-value = 0.201; ANB angle was 2.8 ± 0.5° and 2.9 ± 0.8°, respectively, with *p*-value = 0.471; and YEN angle was 120.1 ± 2° and 119.7 ± 1.7°, respectively, with *p*-value = 0.352).

In all patients of both groups, bilateral Class I molar relationship was achieved. All patients in both groups properly tolerated the appliance. No distalizer debonding occurred in any subject from any group during the treatment period.

STATISTICAL METHOD

The collected data were statistically analyzed using SPSS (Statistical Package for Social Sciences) software (version 9.0, SPSS, Chicago, USA). Descriptive statistics were done (means and standard deviations) for all variables included in the study.

All variables were subjected to Shapiro-Wilk test, which revealed normal distribution for all of them ($p > 0.05$ for all variables). Analyses between both groups for parametric quantitative data were done using independent samples *t*-test, and for qualitative data, using Chi-square test (expected number per cell > 5). The level of significance was defined at p value < 0.05.

Correlations between pretreatment Class II severity and other variables were analyzed using Pearson's correlation coefficient. Differences with less than 5% probabilities were considered statistically significant.

ERROR OF THE METHOD

All reference landmarks, planes and measurements were relocated and measured again by three different operators. Reliability of measurements was estimated by Cronbach's Alpha and Inter-Class Correlation.

RESULTS

The method reliability was excellent, with Cronbach's Alpha and Inter-Class Correlation of more than 0.9 for all measurements in both groups (Table 4). For all variables included in the study, no significant differences were found between boys and girls in both groups (Table 5). Accordingly, for both groups, the results for both boys and girls were analyzed together.

Table 4: Estimation of the reliability of measurements in both groups, by Cronbach's Alpha and Inter-Class Correlation.

	Group II			Group I		
	Cronbach's Alpha	Interclass correlation		Cronbach's Alpha	Interclass correlation	
		R	P value		R	P value
U 6 AP	0.999	0.998	<0.001*	0.999	0.996	<0.001*
Pre-treatment Class II severity	0.999	0.998	<0.001*	0.998	0.993	<0.001*
U 6 VP	0.998	0.993	<0.001*	0.999	0.996	<0.001*
U 6 MD	0.999	0.998	<0.001*	1	0.999	<0.001*
U 6 BL	1	0.999	<0.001*	1	0.999	<0.001*
U 6 ROT	0.998	0.993	<0.001*	0.999	0.998	<0.001*
L 6 AP	0.999	0.996	<0.001*	0.998	0.993	<0.001*
L 6 MD	1	0.999	<0.001*	0.999	0.996	<0.001*
L 1 BL	0.998	0.993	<0.001*	1	0.999	<0.001*
SNA	0.999	0.998	<0.001*	0.998	0.993	<0.001*
CdR - ANS	0.988	0.964	<0.001*	0.998	0.994	<0.001*
SNB	0.998	0.994	<0.001*	1	0.999	<0.001*
CdR - GnR	0.999	0.998	<0.001*	0.999	0998	<0.001*
ANB	0.998	0.994	<0.001*	0.998	0.993	<0.001*
YEN angle	1	0.999	<0.001*	0.999	0.998	<0.001*

*: Significant level at P value < 0.05.

No significant difference ($p = 0.252$) was found in the mean duration of elastics wear per day between both groups (19.8 ± 2 and 20.9 ± 1.5 hours per day, respectively). Also, no significant difference was found ($p = 0.32$) in the amount of force produced by Class II elastics between both groups (194 ± 26g and 201 ± 31 g, respectively).

The mean first molar distalization period in the first group was 19.2 ± 1.6 weeks. It was significantly smaller ($p = 0.001$) than the mean distalization period in the second group, which was

Table 5: Difference between boys and girls, for both groups.

	Group I			Group II		
	Males	Females	P value	Males	Females	P value
Pretreatment Class II severity	2.9±0.9	2.3±0.7	0.127	2.3±1.1	2±0.5	0.558
U 6 AP	4.2±0.8	3.8±0.8	0.301	3.3±0.6	2.7±0.6	0.078
Percent of first molar movement	70.2±14.1	65.7±16.6	0.952	62.2±11.4	53.8±14.3	0.209
U 6 VP	1.3±0.9	0.9±0.8	0.874	1.6±0.8	1.3±0.8	0.634
U 6 MD	5±1.5	5.5±0.9	0.440	4.8±1.2	4.9±1.6	0.917
U 6 BL	3±1.1	2.9±0.9	0.367	2.9±0.9	3.3±0.8	0.905
U 6 ROT	5.6±1.4	5.5±0.7	0.353	6.9±1	7.4±1.2	0.800
L 6 AP	1 ±0.8	1.2±0.9	0.958	2.1±0.9	1.8±0.7	0.491
L 6 MD	3±0.7	3.4±1.7	0.233	4.3±1.2	5.2±1.3	0.536
L 1 BL	4.7±1.2	5±1.9	0.526	6.6±0.9	6.9±1.3	0.634
SNA	0.7±0.3	0.9±0.4	0.711	0.8±0.4	0.9±0.3	0.916
CdR - ANS	0.7±0.4	1±0.5	0.634	1.1±0.4	1.4±0.6	0.874
SNB	1±0.4	0.8±0.3	0.204	0.8±0.3	1±0.5	0.427
CdR - GnR	3.8±1.2	3.5±1.1	0.543	4.1±0.7	4.1±1	0.899
ANB	1.8±0.4	1.5±0.4	0.143	1.6±0.3	1.9±0.4	0.175
YEN angle	4.9±1.1	4.9±1.3	0.988	5.4±0.8	5.5±1.6	0.904
Elastics wearing time (hours/ day)	19.6±1.3	20±1.3	0.544	20.9±1.2	21±0.9	0.816
Treatment Duration (weeks)	18.7±2	19.3±1.6	0.542	23.5±1.4	22.9±1.6	0.404

Quantitative data expressed as mean ± SD.
Chi square test for qualitative data between both groups.
Independent samples *t*-test for quantitative data between both groups.
Significant level at p-value < 0.05.

23.3 ± 2.3 weeks. No significant differences between both groups were observed in all skeletal measurements. No significant correlations between the pretreatment Class II severity and other variables included in the study were observed (Table 6).

Maxillary first molar distalization constituted 67.4 ± 15.1% from the total Class II correction in the first group, which was significantly greater than in the second group, that was 58.5 ± 13% ($p = 0.022$).

Table 6: Correlation between the pretreatment Class II severity and other variables included in the study, in both groups.

	Group I		Group II	
	r	P value	r	P value
U 6 AP	0.403	0.121	0.409	0.116
U 6 VP	-0.137	0.614	0.030	0.911
U 6 MD	0.0	1	0.166	0.540
U 6 BL	-0.007	0.979	0.029	0.915
U 6 ROT	0.083	0.761	-0.031	0.910
L 6 AP	0.068	0.803	-0.301	0.257
L 6 MD	-0.087	0.748	0.240	0.370
L 1 BL	-0.242	0.367	0.171	0.527
SNA	-0.026	0.924	-0.467	0.068
CdR - ANS	-0.133	0.624	-0.117	0.667
SNB	0.081	0.765	0.140	0.604
CdR - GnR	0.345	0.191	0.247	0.356
ANB	-0.334	0.207	0.335	0.204
YEN angle	-0.124	0.648	-0.108	0.690
Elastics wearing time (hours/ day)	0.076	0.780	0.149	0.582
Treatment duration (weeks)	-0.031	0.908	0.046	0.866

Pearson's correlation.

*: Significant level at P value < 0.05.

The amount of maxillary first molar distalization was significantly greater ($p = 0.001$) in the first than the second group (3.9 ± 0.8 and 3 ± 0.6 mm, respectively). No statistically significant differences were found between both groups regarding the quantities of maxillary first molar intrusion, mesiodistal tipping and buccolingual torquing.

Regarding maxillary first molar rotation, distalizing both first and second molars together resulted in more significant first molar rotation than distalizing the first molar alone ($p < 0.001$).

The mandibular incisor labiolingual torquing and the mandibular first molar mesialization and mesiodistal tipping were significantly increased in the second group, indicating more anchorage loss. All these results are summarized in Table 7.

Table 7: Changes in three-dimensional cephalometric measurements, elastics wearing time and treatment duration after maxillary first molar distalization, in both groups.

	Group I	Group II	P value
Sex	Male 11 (36.67%) Female 19 (63.33%)	Male 9 (30%) Female 21 (70%)	0.480
Pretreatment Class II severity	2.5±0.8	2.2±0.9	0.201
U 6 AP	3.9±0.8	3±0.6	**0.001***
Percent of first molar movement	67.4±15.1	58.5±13	**0.022***
U 6 VP	1.2±0.8	1.5±0.7	0.323
U 6 MD	5.2±1.2	4.9±1.4	0.402
U 6 BL	3±1	3.1±0.8	0.605
U 6 ROT	5.6±1.1	7.2±1.1	**<0.001***
L 6 AP	1.1±0.7	2±0.8	**0.004***
L 6 MD	3.2±1.2	4.8±1.3	**0.001***
L 1 BL	4.8±1.5	6.7±1.1	**<0.001***
SNA	0.8±0.5	0.8±0.4	0.692
CdR - ANS	0.9±0.4	1.3±0.5	0.250
SNB	0.9±0.4	0.9±0.5	0.763
CdR - GnR	3.6±1.1	4.1±0.8	0.195
ANB	1.7±0.4	1.8±0.4	0.519
YEN angle	4.9±1.2	5.4±1.2	0.212
Elastics wearing time (hours/ day)	19.8±2	20.9±1.5	0.252
Treatment Duration (weeks)	19.2±1.6	23.3±2.3	**0.001***

Quantitative data expressed as mean ± SD while qualitative data expressed by frequency and percentage.
Chi-square test for qualitative data between both groups.
Independent samples *t*-test for quantitative data between the two groups.
* Significant level at *p*-value < 0.05.

DISCUSSION

Attaining a Class I molar relationship is a fundamental component of appropriate balanced occlusion and facial esthetics.[27] There are controversies regarding the influence of second molar eruption upon various aspects of maxillary first molar distalization. The results of this study did not show any statistically significant differences in different skeletal measurements whether second molar had erupted or not.

The treatment time was significantly shorter, the quantity of maxillary first molar distalization was significantly larger and the amount of rotation was significantly smaller in the group with unerupted maxillary second molar. The differences between both groups were not significant regarding the amount of first molar buccolingual torquing.

Also, the amount of anchorage loss (indicated by mandibular first molar mesial migration and mandibular incisor labiolingual inclination) was significantly greater when the second molar was erupted.

The main outcomes of this study corroborate the results of two lateral cephalometric studies utilizing intra-arch NiTi coil spring with Nance appliance[15] and molar distalizing bow.[28] This approach is efficient to distalize maxillary first molar prior to second molar eruption, attaining the advantages of more efficient first molar distalization and less anchorage loss. Continuing maxillary first molar distalization following maxillary second molar eruption slows down the rate of distalization, that becomes equivalent to starting first molar distalization after second molar eruption.[17]

However, according to two other studies using the XBow appliance[13] and the Pendulum appliance,[29] lateral cephalometric measurements did not show significant differences in the quantity of maxillary first molar distalization and anchorage loss whether the second molar was erupted or not, suggesting that second molar eruption has negligible influence on first molar distalization.

Also, the results of this study support the concept that it is more hazardous to the anchorage if both first and second molars are distalized together, as combined teeth have larger root surface area than a single tooth. Anchorage is less compromised when the first molar is distalized before second molar eruption, resulting in less time-consuming correction of the anchorage loss.[15]

However, mesiodistal tipping of the first molar was not significantly changed in this study, whether distalized before or after second molar eruption. These findings agree with the results of a lateral cephalometric study using the XBow appliance, which concluded that there was no difference in the mesiodistal tipping change of the distalized maxillary first molar whether the second molar was present or unerupted.[13]

This evidence does not agree with the idea that the unerupted second molar would probably impact distal tipping of the first molar to a considerable degree,[14] resulting in more significant first molar mesiodistal tipping than when the second molar is present.[5] Both studies utilized two-dimensional lateral cephalograms to assess alterations in the position of the maxillary first molar.[5,14]

Concerning maxillary first molar buccolingual torquing, this study suggests no significant difference whether the first molar is distalized before or after second molar eruption. According a three-dimensional finite element analysis by Kang et al.,[30] it was more effective to utilize a bone-anchored pendulum appliance to distalize maxillary first molar before second molar eruption, as this resulted in less first molar buccal tipping.

According to the results of this study, if the operator has the choice to distalize maxillary first molars with the Carriere distalizer appliance before or after second molar eruption, earlier initiation of the treatment is more favorable.

As maxillary first molars in all subjects included in this study were distalized with Carriere distalizer appliance, outcomes of this study can be considered precise for patients treated with this distalizer only.

In this study, randomization of patients between both groups implicates that all subjects should have unerupted second molars, starting treatment immediately in the first group and waiting for second molar eruption in the second group. As delaying the treatment was not ethical for the second group, subjects were selected in both groups by a single operator depending on the predetermined selection criteria, except that second molars had already erupted in one group.

CONCLUSION

Maxillary first molar distalization using Carriere distalizer appliance before maxillary second molar eruption is more efficient, less time-consuming and more anchorage-conserving than after second molar eruption.

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ORIGINAL ARTICLE

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Surgical-orthodontic retreatment of a severe skeletal Class III malocclusion following an orthodontic camouflage

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ABSTRACT

Introduction: Class III malocclusions are some of the most difficult occlusal anomalies to be treated. Some patients with this condition may require orthognathic surgery, while others may be treated with dental camouflage. Proper patient assessment and selection remains critical in order to achieve favorable results.

Objectives: This report outlines the case of an 18-year-old male who sought retreatment for a severe skeletal Class III dentofacial deformity after undergoing orthodontic camouflage treatment involving mandibular arch extractions. A treatment plan comprising dental decompensation and orthognathic surgery was implemented in order to achieve optimal facial and occlusal results.

Results: After 28 months of treatment, skeletal and dental correction was achieved and facial features were significantly improved. The orthognathic surgery required a 20-mm sagittal maxillomandibular skeletal correction, combined with a 4-mm correction of the midlines and a 2-mm impaction of the maxilla.

Conclusion: Dental compensation may be a risky treatment alternative for severe dentoskeletal discrepancies. In these patients, orthodontics combined with orthognathic surgery is the recommended treatment option.

Keywords: Orthodontics. Orthognathic surgery. Retreatment. Class III.

RESUMO

Introdução: As más oclusões de Classe III são uma das anomalias oclusais mais difíceis de serem tratadas. Alguns pacientes com essa condição podem precisar de cirurgia ortognática, enquanto outros podem ser tratados por meio da camuflagem ortodôntica. A correta avaliação e seleção do paciente para cada tipo de abordagem permanece uma decisão crítica para se obter resultados favoráveis.

Objetivos: O presente artigo relata o caso de um paciente do sexo masculino, com 18 anos de idade, que procurou tratamento por causa de uma má oclusão esquelética severa de Classe III, após ter se submetido a camuflagem ortodôntica com extração de dentes inferiores. Um plano de tratamento envolvendo descompensação dentária e cirurgia ortognática foi implementado, com a finalidade de atingir resultados faciais e oclusais ideais.

Resultados: Após 28 meses de tratamento, foi alcançada a correção esquelética e dentária, e as características faciais obtiveram uma melhora significativa. A cirurgia ortognática exigiu uma correção esquelética sagital bimaxilar de 20 mm, associada a 4 mm de correção das linhas médias e 2 mm de impacção da maxila.

Conclusão: A compensação dentária pode ser um tratamento alternativo arriscado para discrepâncias dentoesqueléticas severas. Nesses pacientes, a Ortodontia associada à Cirurgia Ortognática é a opção de tratamento recomendada.

Palavras-chave: Ortodontia. Cirurgia Ortognática. Retratamento. Classe III.

INTRODUCTION

When treating Class III dentofacial deformities in patients with little or no further skeletal growth potential, there are two possible treatment options: orthodontic camouflage or orthodontics combined with surgical repositioning of the jaws.[1,2,3] Orthodontic camouflage is viable when treating patients with mild to moderate dentoskeletal discrepancies with acceptable facial aesthetics.[4-7] However, in patients with severe skeletal discrepancies, a combined surgical-orthodontic approach is the preferred method in order to improve facial aesthetics and achieve a stable occlusion.[8-10]

Camouflage orthodontic treatment for severe Class III skeletal discrepancies requires excessive compensatory tooth movements to achieve acceptable results, which may end up leading to adverse aesthetic side effects and other problems such as root resorption, periodontal disease and poor stability.[11] Furthermore, the patient could grow out of the range of successful camouflage treatment, leading to the need for a surgical correction.[12] If the compensatory treatment plan includes the irreversible step of extracting mandibular premolars, additional space management issues may arise during the pre-surgical orthodontic phase of the retreatment.

In this article, the corrective retreatment of a patient with a severe dental and skeletal Class III is presented. The case previously involved an unsuccessful orthodontic camouflage treatment with extraction of two mandibular premolars.

DIAGNOSIS AND ETIOLOGY

An 18-year-old male patient presented for orthodontic retreatment with the chief complaint of unaesthetic facial appearance (Figs 1-4). Previous treatment lasted 24 months and afterwards a retention period of 19 months. During clinical evaluation, a strongly concave profile with accentuated mandibular prognathism and lip incompetence was observed. A severe Class III molar relationship was present, combined with a substantial anterior crossbite (overjet -11 mm) and an excessive retroclination of the mandibular incisors. The mandibular first premolars were extracted during the previous orthodontic treatment, and at this point, 3-mm and 2-mm spaces were present in the right and left extraction sites, respectively. The cephalometric analysis indicated a skeletal Class III pattern due to mandibular prognathism (ANB = -11.5º, SNA = 84.3º, SNB = 95.8º). A substantial retroclination of the mandibular incisors (IMPA = 59º) and a vertical pattern, within the normal parameters (FMA = 24.8º) were also observed (Table 1). Additionally, a transverse asymmetry due to combination of a rotation of the maxilla (2 mm to the right) and the mandible (2 mm to the left) was found.

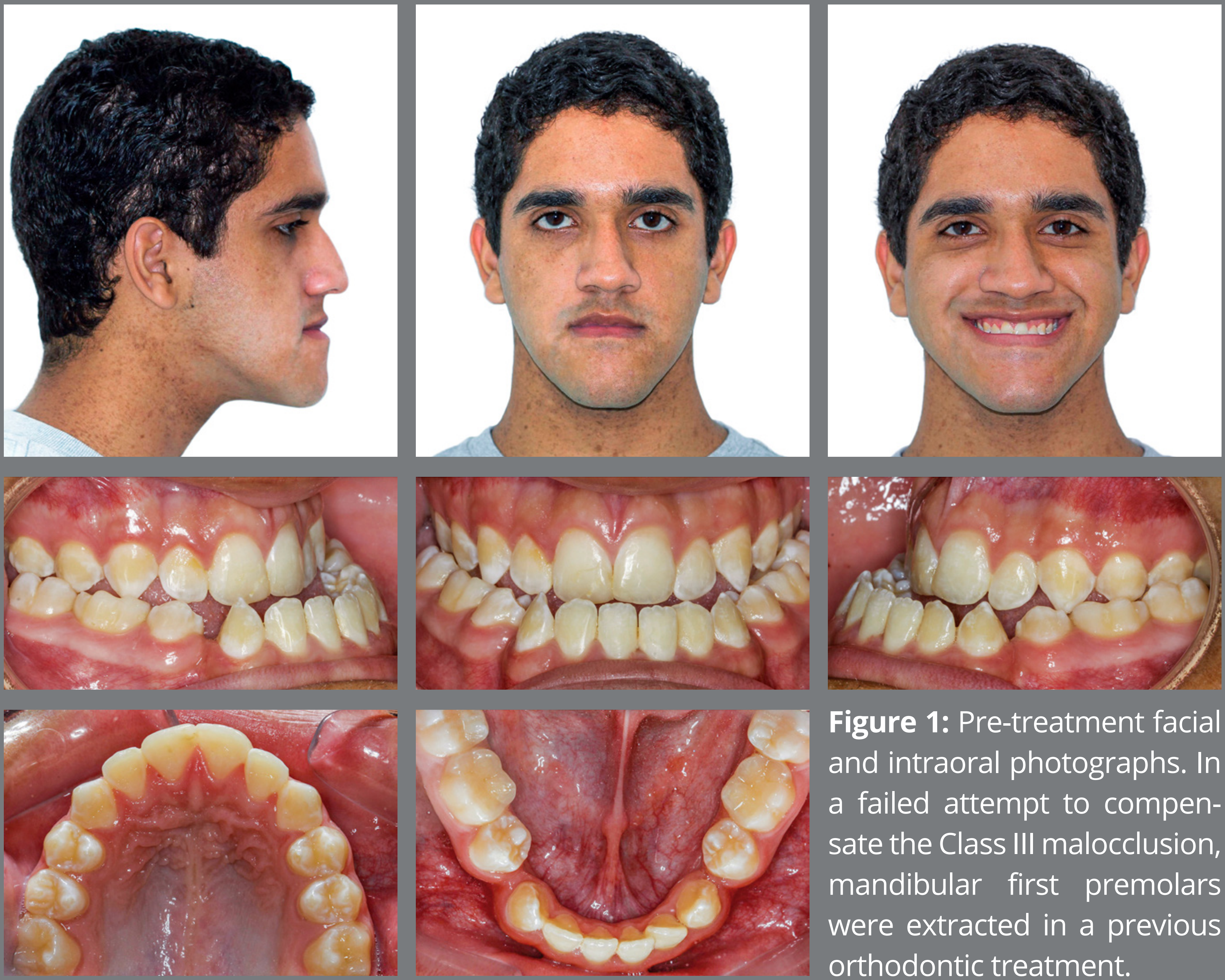

Figure 1: Pre-treatment facial and intraoral photographs. In a failed attempt to compensate the Class III malocclusion, mandibular first premolars were extracted in a previous orthodontic treatment.

Figure 2: Initial panoramic radiograph.

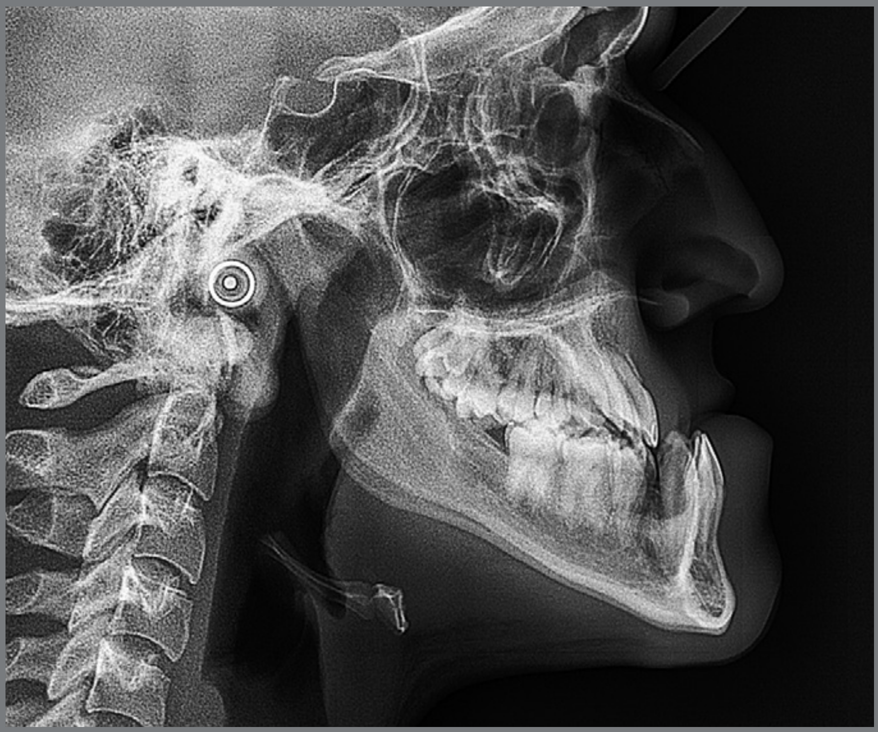

Figure 3: Initial lateral radiograph.

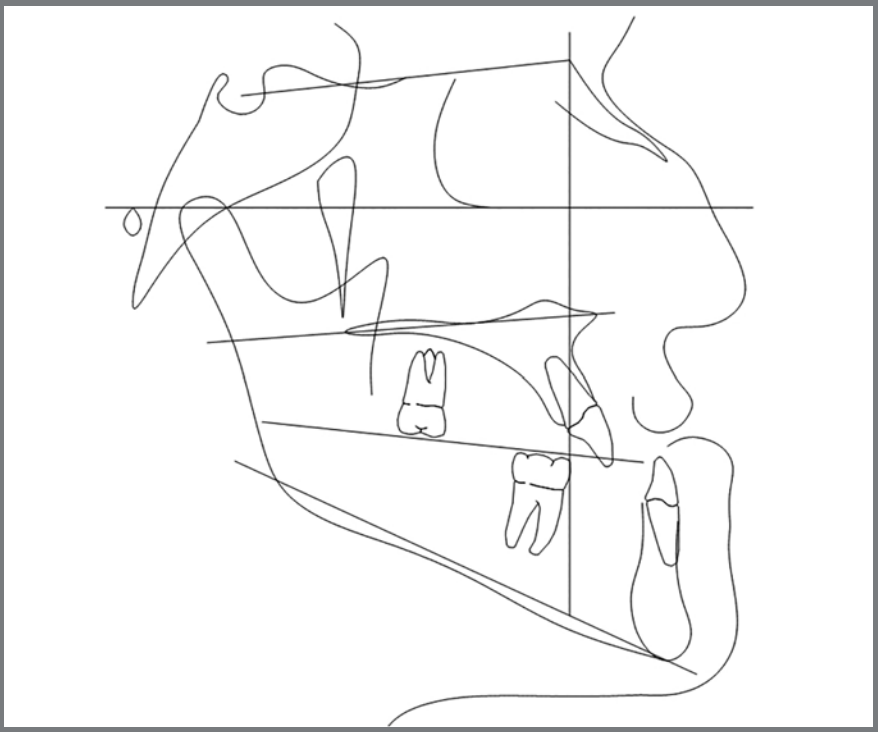

Figure 4: Initial lateral cephalometric tracing.

Table1: Cephalometric data.

Measurement	Norm	Pre-treatment	Pre-surgical	Post-treatment
SNA	82	84.3	84	87
SNB	80	95.8	96.1	85.4
ANB	2	-11.5	-12.1	1.6
FMA	26	24.8	23.6	28.5
IMPA	95	59	90.6	83.5
U1-Palatal Plane	110	114.3	116.6	112.2
Interincisal Angle	130	157.7	126.2	134.2
Lower Lip to E Plane	-2	-0.5	3	-2.1

In the panoramic radiograph, signs of root resorption were observed in the maxillary incisors, and a mild horizontal bone loss was detected in the mandibular incisors.

TREATMENT OBJECTIVES

In order to correct the problems identified in this patient, the following objectives were set: buccal movement of the mandibular incisors, to achieve proper uprighting; mandibular setback combined with the advancement and impaction of the maxilla, to improve facial esthetics, achieve dental correction, and enhance incisor display in the smile. Lastly, mandible and maxilla alignment, to correct dental and facial midlines.

TREATMENT ALTERNATIVES

After reviewing the diagnostic findings, a dental compensatory treatment was discarded, due to the skeletal nature of the Class III deformity. It was concluded that a non-compensatory treatment approach was necessary and consequently, a combined orthodontic and orthognathic surgery treatment plan was proposed, in order to improve facial esthetics and obtain an adequate masticatory function. The pre-surgical orthodontic phase involved the alignment of the dentition within the arches, dental decompensation, leveling of the curve of Spee and coordination of the arches. In order to improve the position of the incisors within the bone bases, it was decided to reopen the mandibular first premolars spaces. The surgical plan included a Le Fort 1 osteotomy for maxillary advancement, impaction and centralization, combined with a bilateral sagittal split osteotomy for mandibular setback and centralization.

TREATMENT PROGRESS

Fixed preadjusted appliances were bonded (Roth prescription, 0.022 x 0.028-in slot) and initial leveling and alignment was performed using NiTi round archwires. Subsequently, rectangular stainless steel archwires were placed to coordinate the arches, and the mandibular first premolar spaces were reopened with the use of NiTi coil springs. Decompensation of the mandibular arch occurred by leveling the curve of Spee and the projection of the mandibular incisors, despite lower lip resistance. After 20 months of treatment, the patient was ready for orthognathic surgery. At this point, the resulting overjet was -17 mm (Fig 5).

Figure 5: Dental decompensation involved the reopening of the mandibular first premolar spaces. The resulting overjet was -17.0 mm.

Pre-surgical records were obtained two weeks prior to surgery, and at the same appointment hooks were placed on passive 0.019 x 0.025-in stainless steel archwires that had been in place for more than six months (Figs 6-8). The orthognathic surgery consisted of 8-mm maxillary advancement with a 2-mm rotation to the left and a 2-mm impaction, combined with 12-mm

Figure 6: Intermediate facial and intraoral photographs. After 20 months of pre-surgical orthodontic treatment, dental decompensation was achieved.

Figure 7: Intermediate lateral radiograph.

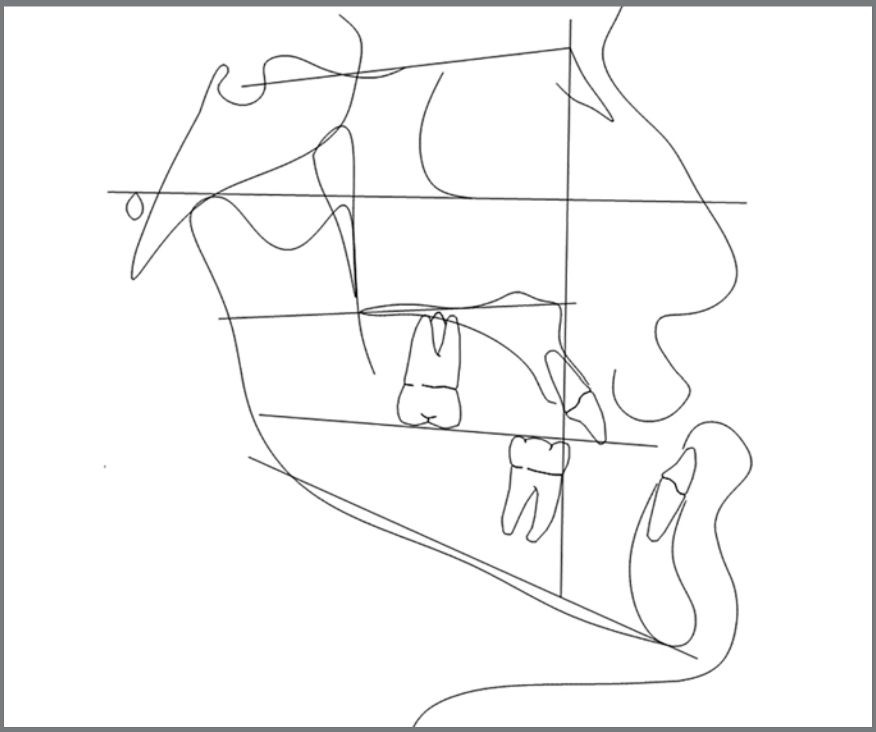

Figure 8: Intermediate lateral cephalometric tracing.

mandibular setback, with a 2-mm rotation to the right. Due to the magnitude of the mandibular setback, the surgeon chose to use large reconstruction plates for better stability of the bone segments. Post-surgical orthodontic treatment continued for eight months, with the objective of achieving a stable final intercuspation of the teeth.

Total treatment time was 28 months and, when combined with the previous camouflage treatment, total time using brackets for this patient was 52 months. For the retention phase, a lower fixed retainer was bonded, combined with an upper Hawley retainer. In order to maintain the space of the mandibular first premolars, temporary fixed retainers were placed and afterwards two fiber-reinforced ceromer-based adhesive bridges were set as temporary space retainers. Dental implants with porcelain crowns were planned as permanent restoration, but the patient decided to postpone this treatment.

TREATMENT RESULTS

A 20.0-mm sagittal maxillomandibular skeletal correction was achieved with orthodontic and orthognathic surgery treatment. Facial features dramatically improved, resulting in a straight facial profile, adequate facial symmetry and a harmonious smile. The resulting facial appearance was balanced, aesthetically pleasing and respecting the individual characteristics of the patient.

The final occlusion had an acceptable intercuspation and canine guidance. Coincident dental and facial midlines were also attained, and a substantial correction of the overjet was achieved (from -17.0 mm prior to the surgery to 2.0 mm at the end of treatment) (Figs 9-12).

A comparison between the pre-surgical and final cephalometrics shows that the ANB angle was normalized, increasing from -12.1º to 1.6º. The 8-mm maxillary advancement resulted in a 3º increase of the SNA angle (from 84º to 87º), and the 12-mm mandibular setback induced a 10.7º decrease of the SNB angle (from 96.1º to 85.4º) (Fig 13).

Figure 9: Final facial and intraoral photographs, after 28 months of surgical-orthodontic treatment. The total maxillomandibular sagittal correction was 20.0 mm.

Figure 10: Final panoramic radiograph.

Figure 11: Final lateral radiograph.

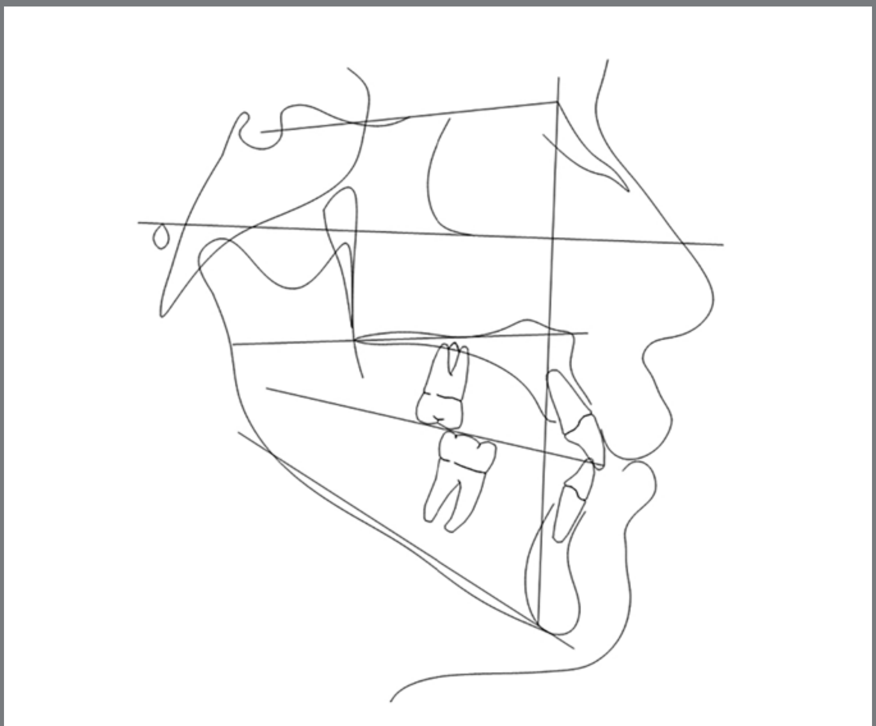

Figure 12: Final lateral cephalometric tracing.

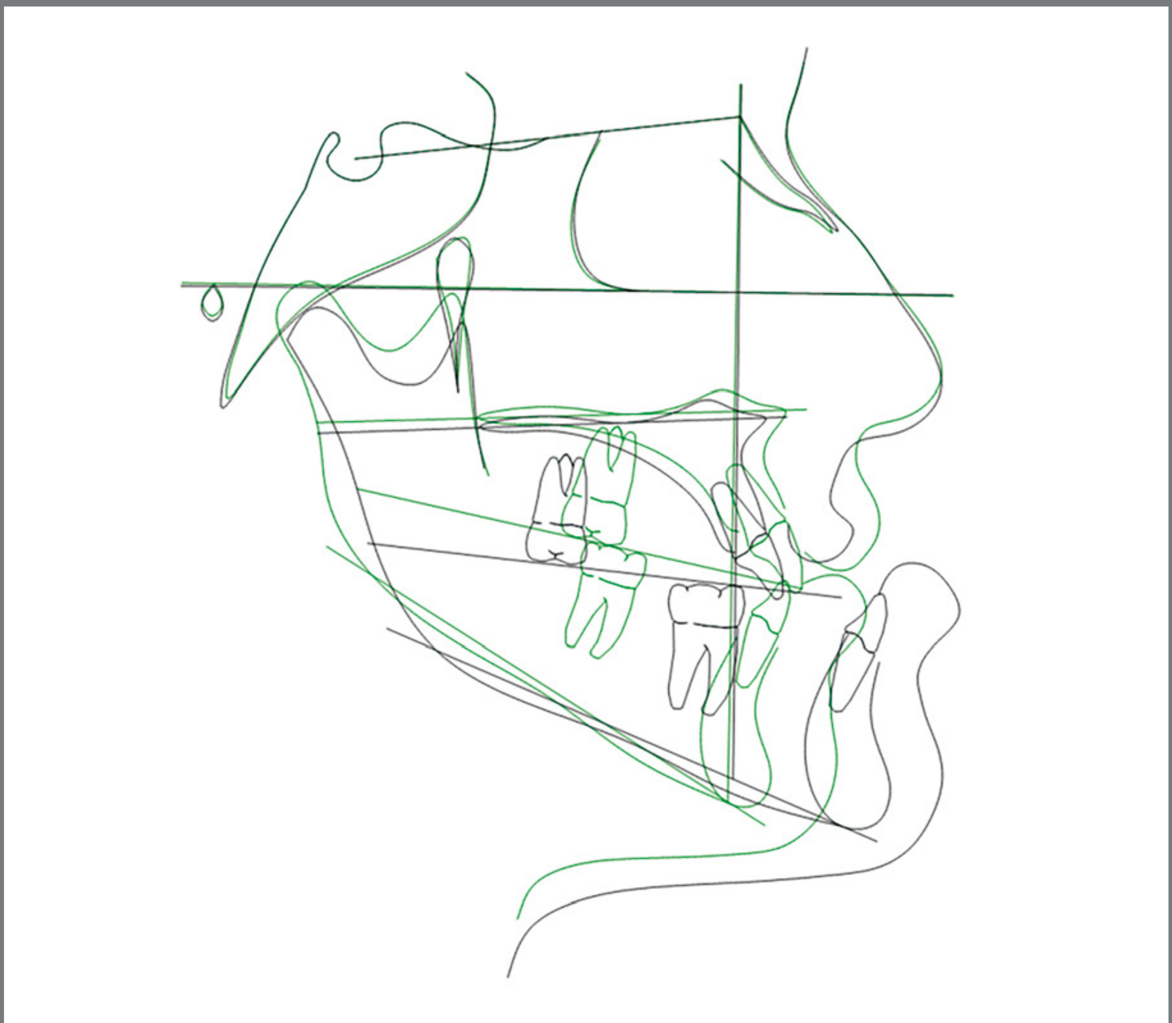

Figure 13: Superimposition of pre-surgical (black) and post-treatment (green) cephalometric tracings.

One year after debonding, the results were stable and the patient was pleased with his facial and occlusal outcome (Fig 14).

Figure 14: Follow up records one year after debonding. Temporary fiber-reinforced ceromer-based adhesive bridges were bonded to replace the missing lower premolars.

DISCUSSION

Camouflage Class III treatment usually relies on the extraction of mandibular premolars to correct the anterior crossbite and disguise the skeletal discrepancy. This treatment approach will typically require an excessive lingual inclination of the mandibular incisors, which can often make the chin appear even more prominent, resulting in an unaesthetic outcome.[13] Other complications may include root exposure by resorption of the cortical plate, with subsequent gingival recession and fremitus.[14,15,16]

A study by Kerr et al.[17] concluded that orthodontic compensation can effectively camouflage the skeletal and dental aspects of the malocclusion if initial ANB is greater than -4.5º and mandibular incisor angulation is greater than 83º. In this case reported, the patient presented for retreatment with an ANB of -11.5º and mandibular incisor angulation of 59º, which combined with poor facial aesthetics, clearly established the need for a surgical-orthodontic retreatment. In order to allow adequate surgical movements, mandibular incisor uprighting was critical; therefore, space reopening in the mandibular arch was necessary during presurgical orthodontics. Options to move mesially the entire mandibular dental arch were considered, but rejected due to the amount of movement required.

Long term stability for this case is a concern, due to the extreme surgical movements that were necessary to correct the skeletal discrepancy in the sagittal plane (8.0-mm maxillary advancement and 12.0-mm mandibular setback). According to a systematic review by Mucedero et al,[18] bimaxillary surgery for Class III correction will be stable when the maxillary advancement is less than 5 to 6.0 mm, and the mandibular setback, less than 7.0 mm.

Looking at this case retrospectively, the camouflage treatment negatively affected the profile, made presurgical orthodontics more complex, and created the need for permanent restorations. Undergoing a retreatment had a negative psychological impact on the patient, due to undesirable results, time consumption and financial burden. A more careful treatment planning based on an accurate growth analysis and realistic goals may have provided enough information to delay the treatment until the patient had stopped growing and surgery could have been performed.

The study of treatment difficulties, such as those presented in this case report, provides a rare opportunity to gain perspective and aim towards an improvement in the quality of care we provide to our patients.[19] Inexperience or lack of training are commonly attributed as causes for complications and unfavorable outcomes. Nevertheless, even orthodontists with vast experience and adequate training may also expose their patients to some degree of unintended irreversible damage. In such cases, limited time for diagnosis and treatment planning due to overcrowded offices may play a part.[20]

CONCLUSIONS

Orthodontics combined with orthognathic surgery is the recommended treatment option for achieving a stable occlusion and facial esthetics in non-growing patients with severe Class III dentoskeletal discrepancies. When considering camouflage treatment for growing patients with this condition, a careful diagnosis is essential in order to develop a customized goal-oriented treatment plan that considers tooth movement limitations, facial characteristics and remaining growth. The presented case highlights the adverse effects that compensatory treatment may have in growing skeletal Class III patients, resulting in the need for a second treatment, combining orthodontics and orthognathic surgery, to achieve optimal treatment results.

AUTHORS CONTRIBUTIONS

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FM.

Data acquisition, analysis or interpretation:

FM, MPC, RJ.

Writing the article:

FM, MPC, RJ.

Critical revision of the article:

FM, MPC, RJ.

Final approval of the article:

FM, MPC, RJ.

Overall responsibility:

FM.

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

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Orthodontist and periodontist's knowledge, attitudes and aspects of clinical practice, regarding fixed lower orthodontic retainers

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ABSTRACT

Objective: This study aimed to assess the knowledge, attitudes, and aspects of the clinical practice of orthodontists and periodontists, regarding lower fixed orthodontic retainers.

Methods: The orthodontists (n=502) and periodontists (n=269) who participated in this cross-sectional observational study received, via e-mail, questions related to the type of lower fixed retainer, dental biofilm accumulation, oral hygiene, and potential periodontal changes. The data were subjected to chi-square and Fisher's exact tests, at 5% significance level.

Results: Both orthodontists (72.3%) and periodontists (58.7%) reported that hygienic retainers accumulate more dental biofilm ($p < 0.05$), and 64.1% of orthodontists and 58.7% of periodontists considered that modified retainers may lead to periodontal changes ($p < 0.05$). There was no significant difference between the dental specialties, regarding the type of lower fixed retainer considered the easiest for the patient to perform hygiene ($p > 0.05$), whereas 48.6% of professionals chose the modified type.

Conclusion: The modified retainer accumulates a greater amount of dental biofilm and, in the perception of orthodontists and periodontists, it may cause periodontal changes.

Keywords: Orthodontic retainers. Orthodontics. Periodontics. Dental biofilm. Knowledge.

RESUMO

Objetivo: O objetivo do presente estudo foi avaliar o conhecimento, as atitudes e os aspectos da prática clínica de ortodontistas e periodontistas, com relação às contenções ortodônticas fixas inferiores.

Métodos: Os ortodontistas (n = 502) e periodontistas (n = 269) que participaram desse estudo transversal observacional receberam, por correio eletrônico, perguntas relacionadas ao tipo de contenção fixa inferior e ao acúmulo de biofilme dentário, higiene bucal e possíveis alterações no periodonto. Os dados foram submetidos aos testes Qui-Quadrado e Exato de Fisher, com nível de significância de 5%.

Resultados: Tanto os ortodontistas (72,3%) quanto os periodontistas (58,7%) relataram que a contenção higiênica acumula mais biofilme dental ($p < 0,05$), e 64,1% dos ortodontistas e 58,7% dos periodontistas consideram que a contenção modificada pode levar a alterações periodontais ($p < 0,05$). Não houve diferença significativa entre os especialistas a respeito do tipo de contenção fixa inferior considerado de mais fácil higienização pelo paciente ($p > 0,05$), sendo que 48,6% dos profissionais escolheram a do tipo modificada.

Conclusão: Na percepção dos ortodontistas e periodontistas, a contenção modificada acumula maior quantidade de biofilme dentário, podendo causar alterações periodontais.

Palavras-chave: Contenções ortodônticas. Ortodontia. Periodontia. Biofilme dentário. Conhecimento.

INTRODUCTION

The use of retainers is desired at the end of orthodontic treatment, to prevent relapse of dental movements.[1-5] Orthodontists are more likely to indicate fixed retainers adapted to the lower arch, because of tooth instability in the region, which requires longer stabilization periods.[1,2,6-10] Fixed retainers are more aesthetic, do not depend on patient cooperation,[6,8,11,12] and may be individualized for the diagnosis and treatment performed.[2,13,14] In this context, the 3x3 fixed bar produced with straight wire bonded to the contralateral canines,[1,12,14] the twisted wire bonded to all lower anterior teeth,[1,9,12,15,16,17] and the modified fixed retainer[1,12,14,16] are the mostly used.

Although acknowledging the benefits of using retainers in orthodontics, studies affirm that dental biofilm accumulation increases with the use of all types of fixed retainers, requiring constant periodontal health assessments to prevent potential periodontal changes.[10,13,17,20]

Clinical studies analyzing periodontal parameters after using different types of lower anterior fixed orthodontic retainers have highlighted the difference in biofilm retention, and the risk of developing periodontal changes in these patients.[14,16-18] However, the cost-benefit ratio of the clinical use of different types of orthodontic retainers has not been defined yet, and there are no studies comparing the advantages and disadvantages of each type of retainer.

Seeking to highlight the existence of cost-benefit ratio differences among the lower fixed retainers mostly used today, and to contribute to orthodontist selection of the retainer type, this study aimed to assess the knowledge, attitudes, and aspects of the clinical practice of orthodontists and periodontists, regarding lower fixed orthodontic retainers.

MATERIAL AND METHODS

The Human Research Ethics Committee of *Centro Universitário da Fundação Hermínio Ometto* approved this study (protocol #71249317.0.0000.5385).

This was a national cross-sectional observational study performed with orthodontists and periodontists. A structured questionnaire was created to assess the knowledge, attitudes, and clinical practices of dentists. Initially, the questionnaire was sent via e-mail to 2,553 dentists specialized in orthodontics (n = 1,565) or periodontics (n = 988). The collection ended 60 days after the initial e-mail was sent, and the data were stored in the Google Forms digital platform.

A total of 850 dentists eligible for the study filled out and returned the questionnaires, which had a final response rate of 33.3%, including 548 orthodontists and 312 periodontists. Seventy-nine questionnaires were excluded due to incomplete information. Thus, the final sample included 771 professionals: 502 orthodontists and 269 periodontists. The sample size provided a test power above 80% at 5% significance level, in all analyses of association of professional specialty with knowledge and performance on lower fixed orthodontic retainers. The analyses were performed in the R Core Team software (R Foundation for Statistical Computing, Vienna, Austria).

The instrument consisted of a drawing, a brief description of the lower fixed retainers — 3x3 bar with straight wire (Fig 1), 3x3 bar with twisted wire (Fig 2), and modified 3x3 bar (Fig 3) —, and nine questions related to knowledge, attitudes, and clinical practice on using retainers (Table 1).

Table 1: Questionnaire.

Lower fixed orthodontic retainer questionnaire
1. What type of lower fixed retainer do your patients mostly use?
2. What retainer do you consider the easiest for the patient to perform hygiene?
3. What retainer do you believe accumulates more dental biofilm?
4. Do you believe that using lower fixed retainer may cause periodontal change?
5. What type of retainer do you believe might cause periodontal change?
6. Do you believe that the number of teeth fixed (bonded) to the retainer may lead to periodontal changes?
7. What means of bonding do you believe may cause periodontal changes?
8. How long do you consider ideal for performing prophylaxis and scaling after installing the retainer?
9. How long do you think the patient should use the retainer?

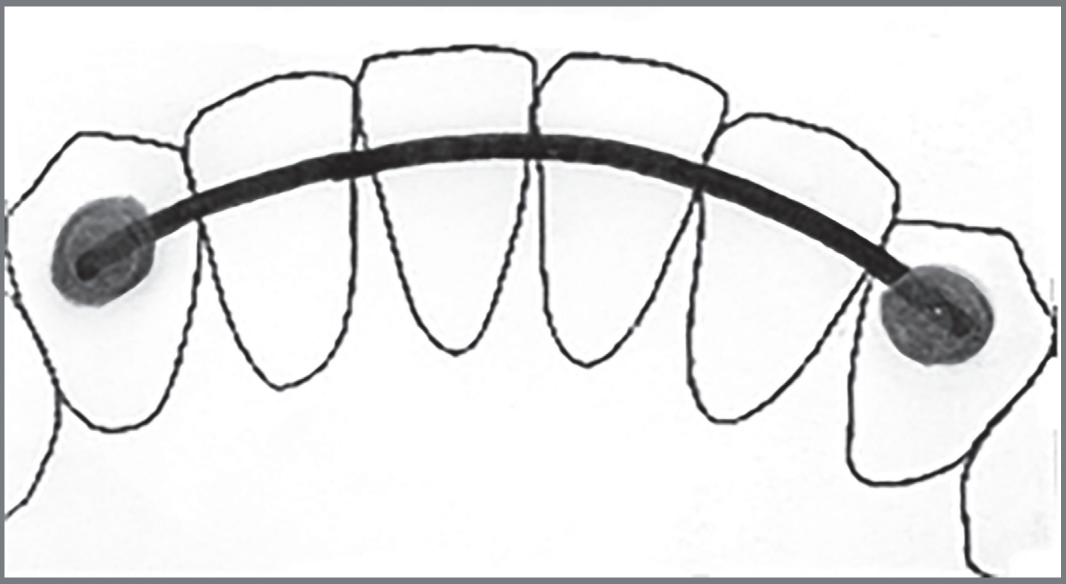

Figure 1: 3x3 bar with straight wire.

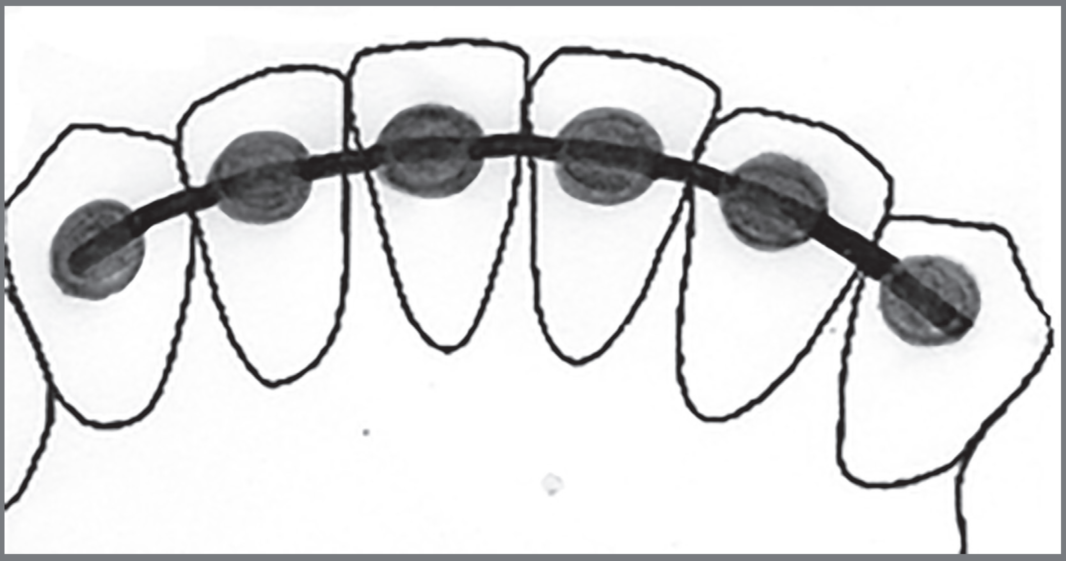

Figure 2: 3x3 bar with twisted wire.

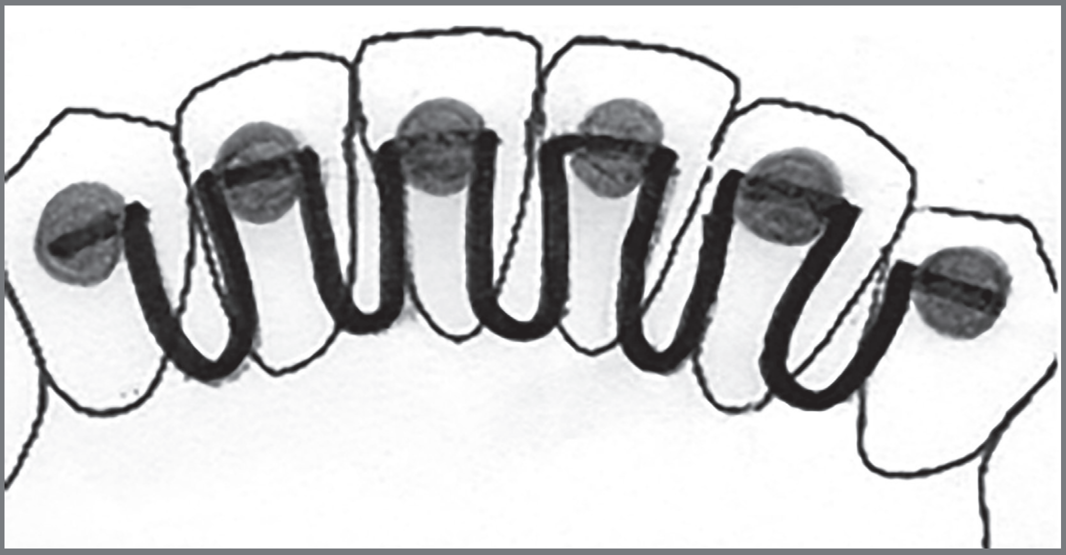

Figure 3: Modified 3x3 bar.

STATISTICAL ANALYSIS

Absolute and relative frequency distribution tables were produced. Chi-square and Fisher's exact tests analyzed the associations between the answers and professional specialties, at 5% significance level. All analyses were performed in the R Core Team software (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

The final sample included 771 specialists, including 502 orthodontists and 269 periodontists. Table 2 presents the association of knowledge, attitudes, and clinical practice of orthodontists and periodontists, regarding the use of lower fixed orthodontic retainers. It was verified that the mostly used retainer, for both specialties, was the straight wire type ($p < 0.05$). The retainer that dentists believe accumulate the greatest amount of dental biofilm is the modified one, considered by 72.3% of orthodontists and 58.7% of periodontists ($p < 0.05$). However, 48.4% of orthodontists and 49.1% of periodontists considered the modified retainer the easiest design for the patient to perform hygiene ($p > 0.05$).

Table 2: Association of knowledge, attitudes, and clinical practice of orthodontists and periodontists regarding the use of lower fixed orthodontic retainers.

Category		Specialty			p-value
		Total	Orthodontics	Periodontics	
		n (%)	n (%)	n (%)	
Mostly used retainer	Straight wire	369 (47.9)	248 (49.4)	121 (45.0)	0.0187
	Twisted wire	199 (25.8)	138 (27.5)	61 (22.7)	
	Modified	203 (67.6)	116 (23.1)	87 (32.3)	
Perception of dental biofilm accumulation	Straight wire	65 (8.4)	30 (6.0)	35 (13.0)	0.0001
	Twisted wire	185 (24.0)	109 (21.7)	76 (28.3)	
	Modified	521 (67.6)	363 (72.3)	158 (58.7)	
Easiest retainer for the patient to perform hygiene	Straight wire	488 (39.6)	197 (39.2)	108 (58.7)	0.8114
	Twisted wire	91 (11.8)	62 (12.4)	29 (10.8)	
	Modified	375 (48.6)	243 (48.4)	132 (49.1)	
Prophylaxis and scaling after retainer installation	Up to 3 months	391 (50.7)	184 (36.7)	207 (77.0)	<0.0001
	3 to 6 months	361 (46.8)	300 (59.8)	61 (22.7)	
	1 year	19 (2.5)	18 (3.6)	1 (0.4)	
Retainer causes periodontal damage	No	230 (29.8)	180 (35.9)	50 (18.6)	<0.0001
	Yes	541 (70.2)	322 (64.1)	219 (81.4)	
Type of retainer that causes periodontal damage	Straight wire	69 (8.9)	42 (8.4)	27 (10.0)	0.0077
	Twisted wire	171 (22.2)	97 (19.3)	74 (27.5)	
	Modified	480 (62.3)	322 (64.1)	158 (58.7)	
	None	51 (6.6)	41 (8.2)	10 (3.7)	
Number of teeth bonded may cause periodontal damage	No	292 (37.9)	223 (44.4)	69 (25.7)	<0.0001
	Yes	479 (62.1)	279 (55.6)	200 (74.3)	
Type of retainer	Only on canines	192 (24.9)	116 (23.1)	76 (28.3)	<0.0001
	All anterior teeth	500 (64.9)	316 (62.9)	184 (68.4)	
	Regardless of bonded teeth	79 (10.2)	70 (13.9)	9 (3.3)	
Time of retainer use	Up to 6 months	45 (5.9)	9 (1.8)	36 (13.4)	<0.0001
	6 months to 1 year	99 (12.8)	42 (8.4)	57 (21.2)	
	Depends on the professional	59 (7.7)	20 (4.0)	39 (14.5)	
	Does not recommend removal	568 (73.7)	431 (85.9)	137 (50.9)	

Still, according to Table 2, there was a difference in professional approach regarding the time to perform prophylaxis and scaling after installing the retainer: Most periodontists (77.0%) indicate up to three months, while orthodontists (59.8%) prefer three to six months ($p < 0.05$). Although most dentists believe that using lower fixed retainers may cause periodontal damages, periodontists (81.4%) reported it more than orthodontists (64.1%). Moreover, 64.1% of orthodontists and 58.7% of periodontists considered that the modified retainer causes more damages to periodontal health ($p < 0.05$). Differences were also verified when considering the number of teeth bonded to the retainer, regarding periodontal damage ($p > 0.05$): 62.9% of orthodontists and 68.4% of periodontists ($p < 0.05$) believe that bonding to every tooth may cause more periodontal changes. It was also noted that most orthodontists (85.9%) and half of the periodontists (50.9%) affirmed they do not recommend removing orthodontic retainers ($p < 0.05$).

DISCUSSION

Lower fixed orthodontic retainers provide stability to tooth positioning after the end of orthodontic treatment, alongside the action of periodontal readaptation forces.[5,19] Therefore, it is essential to know the attitudes and the clinical practice of orthodontists and periodontists, because understanding potential differences may contribute to guide the clinical practice of both type of professionals. Thus, this study chose to include all orthodontists and periodontists, aiming at a more extensive population sample.

The findings of the present study showed that most orthodontists and periodontists consider that the modified retainer accumulates a greater amount of dental biofilm. According to the professionals, the accumulation may be related to wire curvature in the cervical third, and to the use of a greater amount of orthodontic wire, as reported in previous studies.[14,16] The professionals also considered the modified retainer as the type that causes more periodontal damages, presenting higher difficulty to perform oral hygiene, especially because it is bonded to all dental elements, corroborating clinical studies that identified greater biofilm accumulation in this type of retainer.[17,18] However, the literature has reported that, because such retainer has free interproximal areas, it is easier for the patient to perform oral hygiene, especially for using dental floss.[17,20,21]

Orthodontists and periodontists reported the 3x3 fixed retainer with straight wire as the mostly used type. This choice may be related to the ease of production and for considering this retainer to cause less periodontal damage, which may influence the preference of periodontists for it. The preference of orthodontists for this type of retainer had already been reported in previous studies.[1,12]

It is also worth noting that the use of orthodontic retainer, in the opinion of orthodontists (64.0%) and periodontists (82.0%), may cause periodontal damages. However, retainers are indicated because of the action of periodontal ligament fibers, which tend to move the tooth to its original position, before orthodontic treatment, and induce relapse after removing the orthodontic appliance.[22] It was also verified that most orthodontists (84.5%) do not recommend removing lower fixed orthodontic retainers. Among periodontists, 49.8% do not recommend removing the retainer, and 21.7% recommend the removal after six months to one year, because of the potential periodontal damages. The concern with periodontal integrity related to retainers is based on scientific evidence showing that individuals who had never used orthodontic retainers presented a lower rate of clinical attachment loss and drilling depth in the interproximal surfaces, when compared to patients using lower fixed retainers.[23]

In order to prevent periodontal changes, most periodontists recommend performing prophylaxis and scaling up to three months after installing the retainer, but orthodontists believe that the time most indicated is between three and six months. Considering the potential for bacterial colonization in the dental biofilm, each patient should be assessed individually to determine the time to perform prophylaxis and scaling.

Finally, it is important to emphasize that the choice of retainer affects biofilm accumulation and the hygiene challenges of the patient, which may even lead to periodontal changes such as clinical attachment loss and increased drilling depth. There is no ideal type of retainer. The results of this study showed that professionals, both orthodontists and periodontists, are aware of the importance of the use of retainers and its limitations. It is also highlighted that professionals are in charge of assessing individually their cost-benefit, considering oral hygiene and the time of use for each patient, as well as determining the need for professional prophylaxis and scaling, which may vary among patients.

Considering that this study has only assessed the opinion of professionals on fixed orthodontic retainers, further studies are suggested to assess means of performing oral hygiene by patients using orthodontic retainers and the level of toothbrushing of such patients.

CONCLUSION

Orthodontists and periodontists agree that the several types of retainers are different regarding biofilm accumulation, considering that the 3x3 bar with straight wire accumulates less biofilm, followed by the twisted wire retainer, which are easier for performing professional hygiene.

AUTHORS' CONTRIBUTIONS

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Identification of dental calcification stages as a predictor of skeletal development phase

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ABSTRACT

Objective: This study aimed to establish a correlation between the stages of tooth calcification of mandibular canines and second molars with the phases of skeletal development.

Methods: In a consecutive series of panoramic, cephalometric and hand-wrist radiographs of 113 individuals (60 females and 53 males) with an average age of 12.24 ± 1.81 years, the stages of mandibular canine and second molar calcification, cervical vertebrae maturation indicators (CVMI) and skeletal maturity indicators (SMI) were classified. The variables were correlated by means of the Spearman's Rank test: chronological age, SMI, CVMI and tooth calcification stages. In order to assess whether the CVMI and tooth calcification stages were significant predictors of the SMI, an ordinal regression analysis was carried out.

Results: The stages of CVMI (OR = 16.92; CI 95% = 6.45-44.39; $p < 0.001$) and calcification of the second molars (OR = 3.22; CI 95% = 1.50-6.92; $p = 0.003$) were significant predictors of SMI, however similar result was not observed for canines (OR = 0.52, CI 95% = 0.18-1.54; $p = 0.239$). Calcification stage E for boys, and E and F for girls corresponded to the pre-peak phase of pubertal growth. Stages G and H for boys, and F and G for girls coincided with peak of growth. In the final growth phase, the majority of second molars presented with root apex closure (stage H).

Conclusion: The stages of calcification of the second molar may be considered predictors of the stage of skeletal development in the population studied.

Keywords: Carpal bones. Cervical vertebrae. Orthodontics. Radiography.

RESUMO

Objetivo: O presente estudo objetivou estabelecer uma correlação entre os estágios de calcificação dentária de caninos e segundos molares inferiores e as fases do desenvolvimento esquelético.

Métodos: Em uma série consecutiva de radiografias panorâmicas, cefalométricas e de mão e punho de 113 indivíduos (60 meninas e 53 meninos) com idade média de 12,24 ± 1,81 anos, foram classificados os estágios de calcificação do canino e do segundo molar inferiores, indicadores de maturação das vértebras cervicais (IMVC) e indicadores de maturação esquelética (IME). As variáveis foram correlacionadas pelo teste de Correlação de Rank de Spearman: idade cronológica, IME, IMVC e estágios de calcificação dentária. A fim de avaliar se os estágios do IMVC e da calcificação dentária foram preditores significativos do IME, foi realizada uma análise de regressão ordinal.

Resultados: Os estágios de IMVC (OR = 16,92; IC 95% = 6,45-44,39; $p < 0,001$) e calcificação dos segundos molares (OR = 3,22; IC 95% = 1,50-6,92; $p = 0,003$) foram preditores significativos de IME; no entanto, esse não foi o caso com dentes caninos (OR = 0,52, IC 95% = 0,18-1,54; $p = 0,239$). Os estágios de calcificação E para meninos e E e F para meninas corresponderam à fase pré-pico de crescimento puberal. Os estágios G e H para meninos e F e G para meninas coincidiram com o pico de crescimento. Na fase final de crescimento, a maioria dos segundos molares apresentou fechamento do ápice radicular (estágio H).

Conclusão: Os estágios de calcificação do segundo molar podem ser considerados preditores do estágio de desenvolvimento esquelético na população estudada.

Palavras-chave: Ossos do carpo. Vértebras cervicais. Ortodontia. Radiografia.

INTRODUCTION

The correction of malocclusion in patients with skeletal discrepancies and the prognosis for orthodontic treatment are heavily influenced by growth.[1,2,3] Skeletal development is responsible for guiding clinical decisions on the use of extraoral traction and functional appliances, the need for tooth extraction and referral for orthognathic surgery.[4] Therefore, identification of the different phases of growth is a crucial aspect of orthodontic planning.[2]

Skeletal development evaluation using hand-wrist radiographs is traditionally regarded as the gold standard;[5] however, there is a concern over the additional exposure to radiation resulting from the use of this method.[6] More recently, changes in the size and shape of cervical vertebrae has received growing interest as a biological indicator of skeletal development.[2,7] However, the reproducibility of this method has been called into question[6,8] and requires observer experience to assess the growth events.[9]

In this context, dental development should be studied in parallel with other indicators of physiological growth.[1,10,11] Tooth development can be evaluated through the dental eruption phase or tooth calcification stage. It has been reported that calcification stage is considered more reliable.[12] Associations between the stages of tooth calcification and indicators of skeletal development probably allow the clinicians to identify more easily the phases of pubertal growth using panoramic radiography.[11,13,14]

Considering the ethnic variations that influence skeletal development, environmental conditions and regional/climatic variations,[3,15] the methods used to evaluate skeletal development and tooth calcification must be tested on different populations.[16] No prior studies have investigated the applicability of the methods in children and adolescents from the northeastern region of Brazil. Moreover, previous studies focused on isolated comparisons between the hand-wrist maturation methods and tooth calcification stages[4,11,16] or tooth development and cervical vertebrae maturation.[17-20] Given the above, the aim of this study was to assess the correlation between the stages of tooth calcification and skeletal development in a group of Brazilian children and adolescents. The hypothesis of the study was that the cervical vertebrae maturation indicators (CVMI) and tooth calcification stages could be used as skeletal maturity indicators (SMI) in Brazilian children.

MATERIAL AND METHODS

POPULATION AND SAMPLE

The research protocol performed in this study was approved by the Research Ethics Committee from *Universidade Estadual da Paraíba* (CAAE: 24266713.6.0000.5187) and followed the guidelines of the Declaration of Helsinki. The research consisted of an analytical-observational and retrospective protocol. The study comprised of a series of panoramic, cephalometric and hand-wrist radiographs from children and adolescents of the Northeastern region of Brazil. The radiographs were taken for orthodontic purposes, and patients medical records were selected consecutively, thus reducing sampling bias. The individuals who had a prior history of orthodontic treatment, systemic diseases, endocrine/nutritional changes, trauma in the region of cervical vertebrae, hand-wrist or face and developmental anomalies in the teeth were excluded from the study. Patients with radiographic images conducted on different dates were also not eligible to participate. Radiographs of 113 individuals (60 females and 53 males) were included in the sample, with an average age of 12.24 ± 1.81, ranging from 9 to 15.5 years old.

ACQUISITION AND ANALYSIS OF THE RADIOGRAPHS

The digital images were obtained using the Gendex® Orthoralix 9200 (Gendex Dental Systems, Milan, Italy), and analyzed using the software Foton X (CDT Software, Bauru, Brazil) in a dark room with the aid of a 15-in video monitor (Dell Computer Corp., Round Rock, USA). Image manipulation tools were used to adjust brightness and contrast, and to provide a proportional zoom of 150%. The Kappa coefficient was used to assess intra and inter-rater reproducibility. Agreement between the two measurement times (two evaluations were carried out in the pilot phase, with an 10-day interval) was considered excellent (k = 0.99). Inter-observer agreement was also excellent (k = 0.81). The radiographic images were evaluated blinded and separately by two examiners. In the event of a disagreement between the rates, a third examiner was consulted, to establish the stage of development.

EVALUATION OF THE STAGES OF TOOTH CALCIFICATION

The Demirjian method[21] classifies tooth development into eight stages (Table 1). The mandibular canine and second molar on the left side of each panoramic radiograph were evaluated. In the eventuality that the left-side mandibular tooth was missing, the corresponding right-side tooth was examined.

EVALUATION OF CERVICAL VERTEBRAE DEVELOPMENT

The cervical vertebrae maturation indicators (CVMI) proposed by Hassel and Farman[22] and modified by Baccetti et al.[7] consist of observation of anatomic changes in the second, third and fourth cervical vertebrae, examined on cephalometric radiographs. The subjects were grouped according to the growth phase,[18] and the bone development events categorized from stages 1 to 6 (Table 2).

Table 1: Tooth calcification stages according to Demirjian et al.[21] method.

STAGE	EVENTS
A	Calcification of single occlusal points, without fusion of different calcifications.
B	Fusion of mineralization points; the contour of the occlusal surface is recognizable.
C	Enamel formation has been completed at the occlusal surface, and dentin formation has commenced. The pulp chamber is curved, and no pulp horns are visible.
D	Crown formation has been completed to the level of the cementoenamel junction. Root formation has commenced. The pulp horns are beginning to differentiate, but the walls of the pulp chamber remain curved.
E	The root length remains shorter than the crown height. The walls of the pulp chamber are straight, and the pulp horns have become more differentiated than in the previous stage. In molars the radicular bifurcation has begin to calcify.
F	The walls of the pulp chamber now form an isosceles triangle, and the root length is equal to or greater than the crown height. In molars, bifurcation has developed sufficiently to give the roots a distinct form.
G	The walls of the root canal are now parallel, but the apical end is partially open. In molars, only the distal root is rated.
H	The root apex is completely closed (distal root in molars). The periodontal membrane surrounding the root and apex is uniform in width throughout.

Table 2: Cervical vertebrae maturation indicators proposed by Baccetti et al.,[7] and pubertal growth stages according Perinetti et al.[18]

STAGE	OSSIFICATION EVENTS	PUBERTAL GROWTH STAGE
1	The lower borders of all the three vertebrae (C2-C4) are flat. The bodies of both C3 and C4 are trapezoid in shape.	Onset
2	A concavity is present at the lower border of C2. The bodies of both C3 and C4 are still trapezoid in shape.	
3	Concavities at the lower borders of both C2 and C3 are present. The bodies of C3 and C4 may be either trapezoid or rectangular horizontal in shape.	Peak
4	Concavities at the lower borders of C2, C3, and C4 now are present. The bodies of both C3 and C4 are rectangular horizontal in shape.	
5	The concavities at the lower borders of C2, C3, and C4 are still present. At least one of the bodies of C3 and C4 is squared in shape. If not squared, the body of the other cervical vertebra is still rectangular horizontal.	End
6	The concavities at the lower borders of C2, C3, and C4 are still evident. At least one of the bodies of C3 and C4 is rectangular vertical in shape. If not rectangular vertical, the body of the other cervical vertebra is squared.	

EVALUATION OF HAND-WRIST DEVELOPMENT

The skeletal maturity indicators (SMI) proposed by Fishman[23] use four stages of bone development in six anatomic regions located on the thumb, third and fifth fingers, and the radius bone. The bone development events were categorized from stages 1 to 11 (Table 3). The growth phases were categorized in accordance with Gilsanz and Ratib,[24] but the "late puberty" and "post-puberty" phases, corresponding to the final period of growth,[22] were deemed to be the "post-puberty" phase, in order to permit equivalence of comparison with the method employed to assess vertebral development.

Table 3: Skeletal maturity indicators proposed by Fishman,[23] and pubertal growth stages suggested by Gilsanz and Ratib[24].

STAGE	OSSIFICATION EVENTS	PUBERTAL GROWTH STAGE
1	The proximal phalanx of third finger shows equal widths of epiphysis and diaphysis.	Pre-puberty
2	The middle phalanx of third finger shows equal widths of epiphysis and diaphysis.	
3	The middle phalanx of fifth finger shows equal widths of epiphysis and diaphysis	
4	Appearance of adductor sesamoid of the thumb.	Puberty
5	Capping of epiphysis of distal phalanx on the third finger	
6	Capping of epiphysis on middle phalanx on the third finger	
7	Capping of epiphysis of middle phalanx on fifth finger.	
8	Fusion between epiphysis and diaphysis of the distal phalanx on the third finger.	Late puberty
9	Fusion between epiphysis and diaphysis of the proximal phalanx of the third finger.	
10	Fusion between epiphysis and diaphysis of middle phalanx on the third finger.	
11	Fusion of epiphysis and diaphysis seen in the radius.	Post-puberty

STATISTICAL ANALYSIS

The data were analyzed using the IBM SPSS® (IBM Corp. Chicago, Illinois, USA) version 20.0. The level of significance was set at 5%. Initially, a descriptive statistical analysis was carried out in order to characterize the sample. Then the nonparametric and/or ordinal variables chronological age, SMI, CVMI and mandibular canine and second molar calcification (in the non-categorized forms) were correlated through Spearman's Rank Correlation test. The average chronological age for both sexes in the three phases of growth were compared by means of the Kruskal-Wallis test with a subsequent multiple comparison of means, adjusted using the Bonferroni method. Ordinal regression analysis was employed to investigate whether the CVMI stages and tooth calcification were significant predictors of the pubertal growth phase of SMI. The logistic model for ordinal responses has a simple interpretation and higher power.[25,11] The Polytomous Universal Model (PLUM) was applied, incorporating the ordinal nature of the dependent variable into the analysis. Therefore, a logistic regression model was built with proportional-odds and logit function. The tests that evaluate goodness of fit and homogeneity of regression slopes were also conducted in order to analyze the validity of the models constructed.[26]

RESULTS

The results of the Spearman correlation analysis between chronological age, SMI, CVMI and mandibular canine and second molar calcification are presented in Table 4. All the correlation coefficients were positive and significant ($p < 0.01$) for the whole sample and for males and females separately.

Table 4: Spearman's Rank Correlation between chronological age, SMI, CVMI and stages of calcification of mandibular canines and second molars.

		CA	SMI	CVMI	CCS	MCS
TOTAL SAMPLE	CA	1				
	SMI	0.743*	1			
	CVMI	0.771*	0.903*	1		
	CCS	0.789*	0.712*	0.717*	1	
	MCS	0.833*	0.735*	0.662*	0.784*	1
BOYS	CA	1				
	SMI	0.856*	1			
	CVMI	0.886*	0.888*	1		
	CCS	0.789*	0.719*	0.748*	1	
	MCS	0.852*	0.803*	0.735*	0.812*	1
GIRLS	CA	1				
	SMI	0.858*	1			
	CVMI	0.847*	0.896*	1		
	CCS	0.810*	0.801*	0.756*	1	
	MCS	0.827*	0.805*	0.672*	0.760*	1

*Correlation significant at the 0.01 level (2-tailed); CA = Chronological age; SMI= Skeletal maturity indicators; CVMI = Cervical vertebrae maturation indicators; CCS = Canine calcification stages; MCS = Molar calcification stages.

Table 5 displays the distribution of chronological age of the subjects, according to sex and pubertal growth phase of SMI. Significant differences between the sexes and between phases of pubertal growth ($p < 0.05$) were observed. The peak and post-peak growth phases were attained earlier among girls ($p < 0.05$).

Table 5: Distribution of chronological ages for all subjects, grouped by sex and skeletal maturity indicators.

Pubertal growth stage	Chronological age (years)	
	Male	Female
	Mean (SD)	Mean (SD)
Onset	10.67 (1.20)^{Aa}	10.15 (0.78)^{Aa}
Peak	12.91 (1.09)^{Ab}	10.74 (0.92)^{Ba}
End	14.03 (1.03)^{Ab}	13.23 (1.36)^{Bb}

SD = Standard Deviation; Different letters (uppercase in the horizontal and lowercase in the vertical) indicate statistically significant differences ($p < 0.05$), according to the Bonferroni test.

The results of the ordinal regression analysis for the whole sample are displayed in Table 6. The analysis revealed that CVMI and the stages of second molar calcification were statistically significant predictors of SMI. Similar results were observed after performing ordinal regression analysis for the group of boys (Table 7) and girls (Table 8).

Table 6: Results of ordinal multinomial logistic regression analysis for total sample.

Predictors	Estimate	SE	Wald	OR	CI 95%	p-value
CVMI	2.83	0.49	33.04	16.92	6.45-44.39	< 0.001
CCS	-0.65	0.55	1.38	0.52	0.18-1.54	0.239
MCS	1.17	0.39	8.96	3.22	1.50-6.92	0.003

OR = odds ratio; IC = confidence interval; SE = standard error; CVMI = Cervical vertebrae maturation indicators; CCS = canine calcification stages; MCS = Molar calcification stages; Model Fitting Information (-2 log-likelihood intercept only = 205.490; -2 log-likelihood intercept and covariates = 48.208); Pseudo R-Square (Cox and Snell = 0.751; Nagelkerke = 0.854; McFadden = 0.657).

Table 7: Results of ordinal multinomial logistic regression analysis for boys.

Predictors	Estimate	SE	Wald	OR	CI 95%	p-value
CVMI	2.22	0.58	14.43	9.22	2.93-28.98	< 0.001
CCS	-0.43	0.80	0.28	0.65	0.14-3.14	0.594
MCS	1.63	0.72	5.15	5.13	1.25-21.06	0.023

OR = odds ratio; IC = confidence interval; SE = standard error; CVMI = Cervical vertebral maturation indicators; CCS = Canine calcification stages; MCS = Molar calcification stages; Model Fitting Information (-2 log-likelihood intercept only = 97.481; -2 log-likelihood intercept and covariates = 25.568); Pseudo R-Square (Cox and Snell = 0.743; Nagelkerke = 0.838; McFadden = 0.625).

Table 8: Results of ordinal multinomial logistic regression analysis for girls.

Predictors	Estimate	SE	Wald	OR	CI 95%	p-value
CVMI	3.51	0.94	14.04	33.34	5.33-208.66	< 0.001
CCS	-0.91	0.85	1.14	0.40	0.08-2.14	0.286
MCS	1.19	0.56	4.55	3.30	1.10-9.88	0.033

OR = odds ratio; IC = confidence interval; SE = standard error; CVMI = Cervical vertebral maturation indicators; CCS = Canine calcification stages; MCS = Molar calcification stages; Model Fitting Information (-2 log-likelihood intercept only = 105.856; -2 log-likelihood intercept and covariates = 26.938); Pseudo R-Square (Cox and Snell = 0.732; Nagelkerke = 0.860; McFadden = 0.691).

The distribution of the stages of tooth calcification and vertebral development by sex and phases of pubertal growth defined by SMI can be seen in Table 9. In the pre-peak period, a considerable distribution of the stages of tooth calcification was found for both sexes. However, considering the second molar as the more reliable tooth for identifying skeletal development in this sample, it was noted that calcification stage E, for boys, and stages E and F for girls were most common in this period of growth. As far as vertebral development is concerned, stage 2 was the most frequent among boys, while stage 3 was the most frequent among girls.

In the peak growth phase, the majority of second molars were identified in stage G or H among the boys, while for the girls, stages F or G were the most frequent. With regard to cervical vertebrae development, stage 4 predominated among both boys and girls.

In the post-peak period, the second molar in the majority of boys and girls was observed in stage H. Stage 6, attributed to CVMI in the final phase of growth, was the most frequent among both boys and girls. Generally, the stages of tooth calcification in boys were found to be more advanced when compared to girls in the same period of skeletal development.

Table 9: Distribution of calcification stages of teeth and CVMI, according to sex and SMI.

Variable		Sex		
		Male	Female	Total
		n (%)	n (%)	n (%)
ONSET		**Canine calcification stages**		
	D	0 (0.0)	0 (0.0)	0 (0.0)
	E	0 (0.0)	1 (11.1)	1 (3.3)
	F	12 (57.1)	5 (55.6)	17 (56.7)
	G	5 (23.8)	2 (22.2)	7 (23.3)
	H	4 (19.0)	1 (11.1)	5 (16.7)
		Molar calcification stages		
	D	1 (4.8)	1 (11.1)	2 (6.7)
	E	**10 (47.6)**	**3 (33.3)**	**13 (43.3)**
	F	4 (19.0)	**3 (33.3)**	7 (23.3)
	G	4 (19.0)	2 (22.2)	6 (20.0)
	H	2 (9.5)	0 (0.0)	2 (6.7)
		Cervical vertebrae maturation indicators		
	1	5 (23.8)	3 (33.3)	8 (26.7)
	2	**10 (47.6)**	2 (22.2)	**12 (40.0)**
	3	6 (28.6)	**4 (44.4)**	10 (33.3)
	4	0 (0.0)	0 (0.0)	0 (0.0)
	5	0 (0.0)	0 (0.0)	0 (0.0)
	6	0 (0.0)	0 (0.0)	0 (0.0)
PEAK		**Canine calcification stages**		
	D	0 (0.0)	0 (0.0)	0 (0.0)
	E	0 (0.0)	0 (0.0)	0 (0.0)
	F	1 (7.1)	3 (18.8)	4 (13.3)
	G	4 (28.6)	10 (62.5)	14 (46.7)
	H	9 (64.3)	3 (18.8)	12 (40.0)
		Molar calcification stages		
	D	0 (0.0)	1 (6.2)	1 (3.3)
	E	0 (0.0)	2 (12.5)	2 (6.7)
	F	1 (7.1)	**7 (43.8)**	8 (26.7)
	G	**8 (57.1)**	5 (31.2)	**13 (43.3)**
	H	5 (35.7)	1 (6.2)	6 (20.0)
		Cervical vertebrae maturation indicators		
	1	0 (0.0)	0 (0.0)	0 (0.0)
	2	1 (7.1)	0 (0.0)	1 (3.3)
	3	5 (35.7)	5 (31.2)	10 (33.3)
	4	**6 (42.9)**	**9 (56.2)**	**15 (50.0)**
	5	2 (14.3)	2 (12.5)	4 (13.3)
	6	0 (0.0)	0 (0.0)	0 (0.0)

Table 9: (Continuation) Distribution of calcification stages of teeth and CVMI according to sex and SMI.

Variable		Sex		
		Male	Female	Total
		n (%)	n (%)	n (%)
	Canine calcification stages			
	D	0 (0.0)	0 (0.0)	0 (0.0)
	E	0 (0.0)	0 (0.0)	0 (0.0)
	F	0 (0.0)	1 (2.9)	1 (1.9)
	G	1 (5.6)	3 (8.6)	4 (7.5)
	H	17 (94,4)	31 (88.6)	48 (90.6)
	Molar calcification stages			
	D	0 (0.0)	1 (2.9)	1 (1.9)
	E	0 (0.0)	0 (0.0)	0 (0.0)
END	F	0 (0.0)	1 (2.9)	1 (1.9)
	G	3 (16.7)	9 (25.7)	12 (22.6)
	H	**15 (83.3)**	**24 (68.6)**	**39 (73.6)**
	Cervical vertebrae maturation indicators			
	1	0 (0.0)	0 (0.0)	0 (0.0)
	2	0 (0.0)	0 (0.0)	0 (0.0)
	3	1 (5.6)	0 (0.0)	1 (1.9)
	4	3 (16.7)	4 (11.4)	7 (13.2)
	5	4 (22.2)	8 (22.9)	12 (22.6)
	6	**10 (55.6)**	**23 (65.7)**	**33 (62.3)**

Bold values indicate the highest frequencies in the categories of the most reliable predictors of skeletal maturation.

DISCUSSION

Many methods have been suggested for assessing pubertal growth in orthodontic diagnosis and planning. Evaluation of the stages of tooth calcification has the advantage of permitting easy assessment through radiographs present in routine orthodontic documentation.[17,10]

Some studies have shown significant correlation between the stages of tooth calcification and different indicators of skeletal development.[1,10,13,14,17,20] On the other hand, some authors have reported lower or insignificant correlation between skeletal and dental development.[27,28,29] The lack of agreement in previous studies is partially a result of ethnic differences[1,16] and different methods used to evaluate skeletal development and tooth calcification.[17]

Hand-wrist radiography is the most common indicator used by orthodontists to evaluate skeletal development. According to the assumption of Todd,[30] in a uniformly developed skeleton, any area would show the same state of development. More recently, Hoseini et al.[8] suggested that, although biologically the skeletal development in both sexes has a closer correlation with pubertal growth spurts than chronological age, hand-wrist radiographs are not totally appropriate for this purpose, as bones undergo constant change during development. Hand-wrist radiographic images as a tiny part of this system, cannot be representative of the whole skeleton.

The present study aimed to evaluate the correlation between phases of skeletal development based on hand-wrist bones maturation[23] and a cervical vertebrae development method, as a second reference for maturity,[7] in respect of tooth calcification.[21] The practical goal was to estimate the applicability of the use of panoramic radiographs as a clinically useful resource for identifying the phases of pubertal growth.

Through the findings of this study, the methods used to evaluate hand-wrist and cervical vertebrae development were found to be equivalent for the whole sample and separately by sex. Moreover, the appearance of the events of skeletal development was seen to occur earlier in girls than in boys, in agreement with previous findings on different populations.[1,13,14,29]

In the present sample, the Spearman correlation between the SMI and stages of canine and second molar calcification were significant and high for boys ($r = 0.719$ and 0.803) and girls ($r= 0.801$ and 0.805). The same was found between CVMI and tooth calcification, though with slightly lower correlation values for the second molar in boys ($r = 0.735$) and girls ($r = 0.672$) and the canines in girls ($r = 0.756$). However, Lopes et al[11] asserted that a high correlation is a natural tendency, because both tooth calcification and skeletal development are events that are in progress in growing individuals. Thus, a high correlation coefficient does not furnish information on whether the stage of tooth calcification is satisfactory for identifying the stage of skeletal development.[10]

For this reason, an ordinal regression analysis was performed, which showed that only the second molar was considered a significant predictor of skeletal development. Therefore, it is important to highlight that previous studies recommending the use of stages of calcification of mandibular canines as indicators of pubertal growth were limited to an analysis of correlation.[4,14]

Many authors[10,13,14,15,17] have also found that calcification stages of the mandibular second molar showed greater correlation with skeletal development than other teeth, as it tends to take longer to develop to a more advanced age, normally presenting apex closure at the age of 16 years.[12,17]

For the second molars evaluated in this study, it was noted that the calcification stage E for boys and stages E and F for girls corresponded to the period preceding the peak of pubertal growth, estimated by means of SMI method. In these children, stage 2 of the CVMI was most frequent among boys, and stage 3 among girls. Kumar et al.[17] found that for both sexes, stage E of the mandibular second molar was the most common in the stage 2 of the CVMI. In Brazilian children,[11] stages E and F for boys and D and E for girls were correlated to the pre-peak growth phase, estimated with the hand-wrist method.

In the peak growth period, the majority of second molars were identified in stage G or H in boys and F or G in girls. In both sexes, there was a predominance of stage 4 in the CVMI. Stages 3 and 4 of CVMI also represented the peak of pubertal growth in the children studied by Giri et al.[15] in Nepal; and for these children, stages F and G of mandibular second molar calcification for females and stage G for males were correlated to peak pubertal growth. According to Kumar et al.[17], in this phase, stages F and G was most frequent in stages 3 and 4 of the CVMI, similar to what was previously reported by other authors.[14]

In the post-peak period of growth, the second molar of the majority of boys and girls was observed in stage H, as evidenced by Litsas et al.[20] in Greek children. In the present study, stage 6 attributed to CVMI in the final phase of growth was the most frequent for both boys and girls. In the findings of Kumar et al.[17], stage H was associated with stages 5 and 6 of the CVMI (end of the growth spurt). In the final phase of pubertal growth, the majority of teeth evaluated by Lopes et al[11] had already achieved apical closure. In girls, however, the majority of second molars were still found in stage G, evidencing a more accelerated tooth calcification in boys. This observation was confirmed by the present study, and has also been previously described.[1,13,14]

Thus, the simplicity of the evaluation of some teeth development according to Demirjian stages[21] and correlations previously found between the stages of tooth calcification and the phase of pubertal growth[15,17,20,11] allow to regard tooth development as a tool for an initial assessment of the child's skeletal development. Caution is recommended when interpreting the results of this study and other cross-sectional research, because of the limited evaluation of growth. While the hypothesis of this study was accepted, since CVMI and tooth calcification stages are considered significant predictors of the SMI in Brazilian children, it is important to emphasize that the clinical use of stages of tooth calcification to establish phases of skeletal development cannot be derived from the present study. Lastly, the results presented here are an original contribution to the discussion on correlation between different evaluation methods to estimate the skeletal development in individuals in growth phase with orthodontic needs.

CONCLUSIONS

The stages of calcification of the left mandibular second molar were considered to be better predictors of the skeletal development than that of the mandibular canine, and may be used in a preliminary identification of the phases of pubertal growth in the population studied. In the eventuality that the left-side mandibular tooth is missing, the corresponding, right-side one is examined. The timing of peak growth identified by SMI coincided with the calcification stages G and H for boys and F and G for girls, and stage 4 of CVMI.

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Factors associated with the morphology of the mandibular symphysis and soft tissue chin

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ABSTRACT

Objectives: This study aimed to (I) assess the morphology of the symphysis and soft tissue chin associated with sex, age and sagittal/vertical skeletal patterns, and (II) identify the individual and combined contributions of these variables to different portions of the symphysis.

Methods: This cross-sectional study included 195 lateral cephalometric radiographs from untreated adults. Alveolar, basal, and soft tissue of the symphysis were measured by an X/Y cranial base coordinate system, and divided in accordance to four predictor variables: sex, age, and sagittal/vertical skeletal patterns. Parametric tests were conducted for comparison and correlation purposes, while multiple regression analysis was performed to explore combined interactions.

Results: Alveolar inclination is related to sagittal and vertical patterns, and both explained 71.4% of the variations. Alveolar thickness is weakly predicted and poorly influenced by age. Symphysis height was 10% higher in males, and associated with a vertical skeletal pattern and sex, and both explained 43.6% of variations. Basal symphyseal shows an individual thickness, is larger in males, and vertically short-positioned with age. Soft tissue chin is not necessarily related to the size of the underling skeletal pattern, and enlarges with age, even in adulthood.

Conclusions: The symphysis and surrounding tissues are influenced by sex, age, and sagittal and vertical patterns, acting differently on the alveolar, basal and soft tissue portions. Sagittal and vertical skeletal patterns are the strongest association on alveolar symphysis inclination, whereas sex and age acts on the vertical symphysis position and soft tissues thickness.

Keywords: Chin. Symphysis. Morphology. Adult. Genioplasty.

RESUMO

Introdução: O presente estudo objetivou: 1) avaliar a morfologia da sínfise mandibular e dos tecidos tegumentares do mento, associada ao sexo, idade, padrões sagital e vertical; e 2) identificar as contribuições dessas variáveis, individualmente ou combinadas, às diferentes regiões da sínfise. **Métodos:** Este estudo transversal incluiu 195 radiografias cefalométricas laterais de adultos não tratados ortodonticamente. Os tecidos alveolar, basal e mole da sínfise foram medidos por um sistema de coordenadas x, y e z da base do crânio e divididos de acordo com quatro variáveis preditoras: sexo, idade e padrões esqueléticos sagitais e verticais. Testes paramétricos foram conduzidos para fins de comparação e correlação, enquanto a análise de regressão múltipla foi realizada para explorar as interações combinadas. **Resultados:** A inclinação alveolar está relacionada aos padrões sagitais e verticais, e ambos explicaram 71,4% das variações. A espessura alveolar é fracamente prevista e pouco influenciada pela idade. A altura da sínfise foi 10% maior no sexo masculino e esteve associada ao padrão esquelético vertical e ao sexo, sendo que ambos explicaram 43,6% das variações. A sínfise basal mostra espessura individual, é maior no sexo masculino e verticalmente curta com a idade. O tecido mole do mento não está necessariamente relacionado ao tamanho do padrão esquelético subjacente e aumenta com a idade, mesmo na idade adulta. **Conclusões:** A sínfise e os tecidos circundantes são influenciados pelo sexo, idade e padrões sagitais e verticais, que atuam de forma diferenciada nas porções alveolar, basal e de tecidos tegumentares. Os padrões esqueléticos sagitais e verticais são a associação mais forte na inclinação da sínfise alveolar, enquanto o sexo e a idade atuam na posição vertical da sínfise e na espessura dos tecidos tegumentares.

Palavras-chave: Queixo. Sínfise. Morfologia. Adulto. Mentoplastia.

INTRODUCTION

The mandibular symphysis is the anatomical anterior part of the mandible composed of cortical and alveolar bones. Differently, the chin, or mentum, is the projected part of the mandibular symphysis, constituting a feature unique to modern humans.[1] In turn, the adjacent soft tissue below the lower lip is called soft tissue chin. The symphysis and adjacent tissues make up an interactive and complex anatomical structure, didactically divided into three portions: two hard tissues and one soft tissue. The hard tissues constitute the alveolar and basal portions. The alveolar ridge accommodates the mandibular incisors, and its inclination usually matches the long axis of the alveolar symphysis.[2] The basal portion constitutes the mandibular symphysis itself, with a more apical location when compared to the alveolar portion.[3] On the other hand, the soft tissue chin represents the integumental mentum, which is supported and designed by the underlying basal symphysis, dentoalveolar projection, and soft tissue thickness.[4]

Identifying the factors associated with the morphology of the symphysis and adjacent structures can be useful for basic and applied sciences. Alveolar symphyseal inclination can be affected by anteroposterior orthodontic movement in compensatory or decompensatory treatments for skeletal discrepancies,[5] and also in arch-perimeter changes for tooth-size discrepancies.[6] This aspect has been a concern when considering a safe anteroposterior movement of the mandibular incisors, preventing periodontal damage such as bone fenestration and dehiscence.[7] The inclination of the long axis of the basal symphysis is one of the characteristics used to predict mandibular rotation and projection during growth.[8] This symphyseal site can also provide autogenous bone for bone grafting prior to dental implant placement.[9] Furthermore, both bone and chin soft tissue play crucial roles in facial aesthetics, and are therefore vital when making surgical case decisions in cases of genioplasty.[10]

Previous cross-sectional[3,4,11-17] and longitudinal[18-20] studies have shown that the morphology and position of the symphysis and adjacent structures can be influenced by age, sex, and sagittal/vertical skeletal patterns. Inconsistent results were found in some of these studies, probably because unclear information is available about the influence of each of these factors on the symphysis morphology. Despite some studies[12,17] have used a multivariate statistic for data analysis, age was a factor not considered. In addition, proper chin position is a relevant goal of orthodontic treatment, and understanding the influencing factors is encouraging.

The present study hypothesized that different regions of the symphysis and adjacent tissues are influenced individually or in association by different predictor variables. Thus, the aim of this study was to assess the contributions of sex, age, and sagittal/vertical patterns to the morphology variation of the alveolar, basal, and soft tissue portions of the symphysis and surrounding tissues, using a multiple regression model.

MATERIAL AND METHODS

This cross-sectional cephalometric study was approved by the Institutional Review Board/Federal University of Uberlândia (Uberlândia/MG, Brazil), with the protocol number 247/07. The STROBE guidelines for observational studies were followed.[21]

SAMPLE

A sample of 195 lateral cephalometric radiographs of untreated white adults (100 males and 95 females) was consecutively selected from the pretreatment orthodontic records of 563 patients. The sample presented varying degrees of skeletal severity, and was adjusted to balance the number of subjects with anteroposterior and vertical skeletal patterns.

The following inclusion criteria were followed: adult patients (males > 18y and females > 16y); facial symmetry (detected by facial photographs); presence of all teeth, except third molars; and good quality digital lateral cephalometric radiographs, teeth in maximum intercuspal position, lips at rest and a natural head position. According to the exclusion criteria, radiographic images presenting advanced periodontal disease; signs of facial or dental trauma; syndromes or congenital craniofacial anomalies, such as cleft lip or palate; and previous orthodontic, prosthetic, or surgical procedures, were not considered.

The total sample was divided according to the predictor variables sex, age, and sagittal and vertical skeletal patterns. Age division was distributed as follows: younger (< 25 years old, n = 89); middle (≥ 25 and < 35 years old, n = 49), and older (≥ 35 years old, n = 57). The sagittal pattern was divided according to: skeletal Class I (well-balanced face, with ANB angle between 0° and 4°, n = 60); skeletal Class II malocclusion (ANB > 4°, n = 64), and skeletal Class III malocclusion (ANB < 0°, n = 71). The vertical pattern was divided according to the mandibular plane angle, with normodivergent (> 28 SN.GoGn < 34°, n = 62), hyperdivergent (SN.GoGn ≥ 34°, n = 67) and hypodivergent (SN.GoGn < 28°, n = 66). Table 1 describes the sample characteristics.

Table 1: Sample characteristics (n = 195).

		Horizontal pattern				Vertical pattern				Age			
		Class I	Class II	Class III	n	Low MP-angle	Medium MP-angle	High MP-angle	n	< 25	25,0 – 34,9	≥ 35	n
n		60	64	71	195	66	62	67	195	89	49	57	195
Sex (frequency)	Male	30	30	40	100	37	31	32	100	53	20	25	98
	Female	30	34	31	95	29	31	35	95	36	29	32	97
Age (years)	Mean (SD)	24.0 (6.2)	3.2 (9.1)	30.7 (11.1)		28.8 (10.4)	29.1 (9.1)	28.7 (9.4)		20.6 (2.5)	28.8 (2.5)	41.3 (6.1)	
	Min./ Max.	16.4/ 42.7	16.0/ 55.0	16.0/ 63.0		16.0/ 63.0	16.0/ 53.0	16.4/ 55.0		16.0/ 24.0	25.0/ 34.0	35.0/ 63.0	
MP-angle	Mean (SD)	30.0 (5.8)	31.5 (7.6)	30.0 (5.6)		23.7 (3.1)	30.2 (1.7)	37.5 (3.1)		29.9 (6.1)	31.1 (5.4)	30.7 (7.3)	
	Min/ Max	16.0/ 43.5	14.0/ 46.0	17.0/ 42.0		14.0/ 28.0	28.0/ 33.0	34.0/ 46.0		14.0/ 46.0	17.0/ 42.0	16.0/ 44.5	
ANB (angle)	Mean (SD)	2.3 (1.2)	6.8 (1.6)	-3.3 (2.3)		-0.9 (4.7)	1.7 (4.6)	2.6 (4.4)		1.5 (4.2)	2.3 (4.7)	1.5 (5.11)	
	Min/ Max	0.0/ 4.0	4.5/ 12.0	-11.0/ -0.5		-11.0/ 9.0	-6.0/ 12.0	-8.0/ 9.0		-11.0/ 10.0	-6.0/ 12.0	-8.0/ 10.0	

CEPHALOMETRIC ASSESSMENT

Cephalograms were traced by hand on acetate paper in a darkened room, by an experienced and calibrated orthodontist. Eleven angular and linear measurements were obtained based on sixteen cephalometric landmarks (Fig 1 and Table 2). Variables were grouped in accordance with the alveolar, basal and soft tissue portions of the symphysis and surrounding tissues. Digital cephalometric radiographs were obtained with standardized settings (90 kV, 12.6 mA).

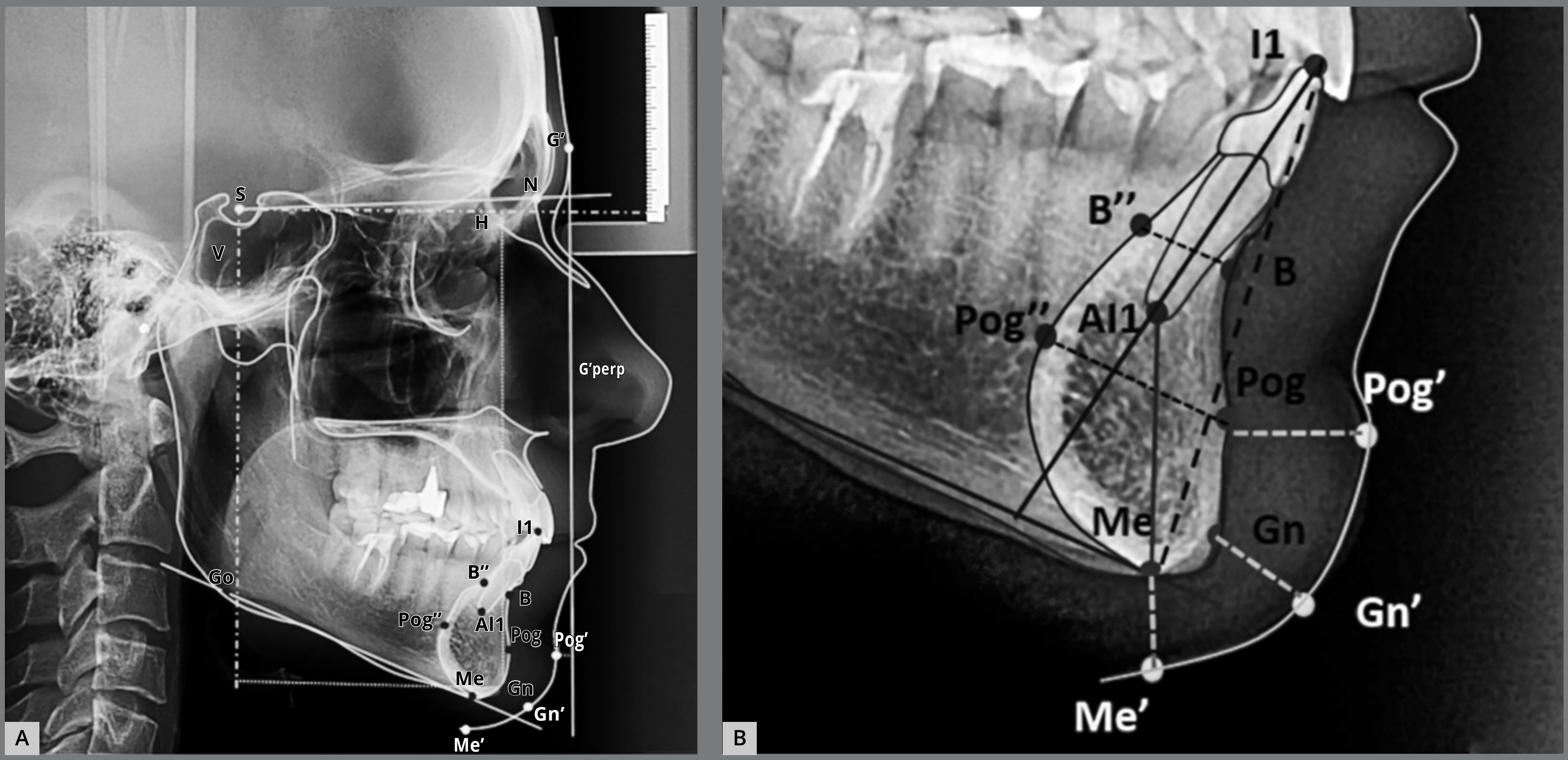

Figure 1: Landmarks, lines, and planes. S (midpoint of sella turcica), A (most concave point of anterior maxilla), N (most anterior point on frontonasal suture), B (most concave point on mandibular symphysis), B" (most posterior point on alveolar mandibular symphysis projected by a parallel line to MP passing through point B), Go (most inferior point on mandible angle), Gn (most anteroinferior point on mandibular symphysis), Gn' (gnathion soft tissue), G' (glabella soft tissue), I1 (Incisor edge of the mandibular incisor), Al1 (root apex of the mandibular incisor), Me (lowest point on mandibular symphysis), Me' (soft tissue menton), Pog (most anterior point of mandibular symphysis), Pog' (soft tissue pogonion), and Pog" (most posterior point of basal mandibular symphysis projected by a parallel line to MP passing through Pog point). S-N (line connecting S and N), H (sagittal line from the S at 7° inferior to the original S-N line), V (line from S perpendicular to H), MP (mandibular plane, line connecting Go and Me), G'-perp (line from G´ perpendicular to H line), and L1 (line connecting incisal edge and root apex).

Table 2: Cephalometric measurements.

Variable	Identification	Type	Definition
Alveolar symphysis			
Inclination	IMPA	Angular (degrees)	Angulation between the long axis of mandibular incisor (L1-AL1) and the mandibular plane (MP).
Thickness	B-B”	Linear (mm)	Linear distance between points B and B”.
Height	I1-Me	Linear (mm)	Linear distance between points I1 and Me, representing the alveolar and basal heights, and including the mandibular incisor.
Basal symphysis			
Inclination	AL1Me.MP	Angular (degrees)	Angulation between the height of basal symphysis (AL1-Me) and the mandibular plane (MP).
Thickness	Pog-Pog”	Linear (mm)	Linear distance between points Pog and Pog”.
Horizontal position	V-Gn	Linear (mm)	Minor linear distance between line V and point Gn, representing the sagittal position of the symphysis on the face.
Vertical position	H-Gn	Linear (mm)	Minor linear distance between line H and point Gn, representing the vertical position of the symphysis on the face.
Soft tissue chin			
Projection in relation to Glabella	G’perp-Pog’	Linear (mm)	Minor linear distance between line G’perp and point Pog’, representing the sagittal projection of the chin.
Thickness (Pog)	Pog-Pog’	Linear (mm)	Minor linear distance between points Pog and Pog’, representing the anterior thickness of the chin soft tissue.
Thickness (Gn)	Gn-Gn’	Linear (mm)	Minor linear distance between points Gn and Gn’, representing the more anteroinferior thickness of the chin soft tissue.
Thickness (Me)	Me-Me’	Linear (mm)	Minor linear distance between points Me and Me’, representing the inferior thickness of the chin soft tissue.

STATISTICAL ANALYSIS

A *post-hoc* power analysis was undertaken using G*Power software version 3.2.9.2. (Germany)[22]. Analysis was based on total sample size and number of tested predictors, by using multiple linear regression model of analysis, with fixed effects (alpha = 0.05; effect size = 0.09). Sample power was 0.93. To assess the reliability of the method, 80 lateral cephalometric radiographs were randomly selected and re-measured by the same researcher with an interval of at least two weeks. The intra-class correlation coefficient (ICC) at $p<0.05$ was used to determine intra-examiner reliability followed by Bland-Altman plots analysis.

The primary outcome variables (Y) were: alveolar, basal, and soft tissue portion characteristics. The predictor variables (X) were: sex, age, sagittal and vertical skeletal patterns. Data were analyzed using comparative statistics for age, sagittal and vertical patterns (One-way ANOVA and Kruskal-Wallis tests, followed by Tukey test and pairwise comparison analysis, respectively). Sex groups were evaluated using *t* test. Pearson correlation analysis was performed to identify statistically significant variables. Multiple linear regression was undertaken using multivariate general linear models, adjusting for potential confounders, and in order to evaluate interaction between the independent factors and each predictor variable. 2-tailed statistical significance was set at $p<0.05$, carried out using the software SPSS 23.0 for Windows (IBM Corp, Armonk, NY).

RESULTS

RELIABILITY

Figure 2 shows all cephalometric measurements with CCI values and respective Bland-Altman plots. The results revealed a high intra-examiner agreement for most variables. The G'perp-Pog' (CCI=0.7207) was an exception, probably due to limitations in the geometric arrangement and distance in measuring. The cephalometric method used in this study is a reliable tool to evaluate the morphology of the symphysis and adjacent tissues.

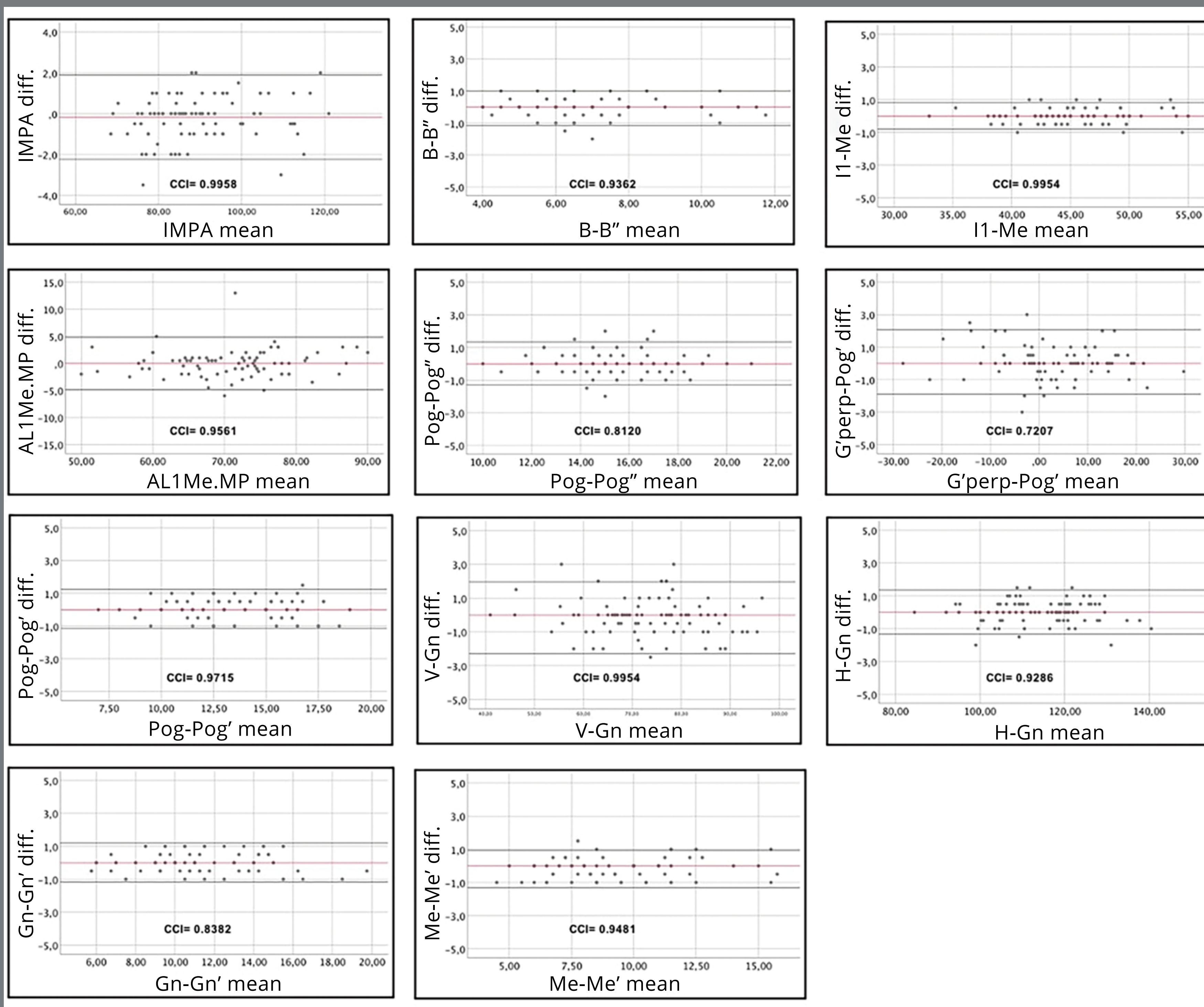

Figure 2: Bland-Altman plots with the mean difference of measurements, 95% CI and the CCI values of each variable.

SAMPLE CHARACTERISTICS

Sample characteristics showed similar distributions of sex, and sagittal and vertical discrepancies (Table 1).

UNIVARIATE ANALYSIS

The alveolar inclination was similar for both genders, although influenced by the sagittal and vertical patterns. It was anteriorly inclined in Class II and sagittal cases, and posteriorly inclined in Class III and vertical cases. Alveolar symphyseal thickness was not influenced by age or sex, and was thinner in individuals with a Class III skeletal combined with a hyperdivergent pattern. Symphyseal height was longer in the vertical pattern and 10% higher in males. Basal symphyseal inclination was less influenced by the sagittal pattern. Basal symphyseal thickness was greater in males and not associated with any other variable. The sagittal and vertical position was influenced by the sagittal and vertical skeletal patterns, and vertically reduced with age. Projection of the chin's soft tissue was associated with the sagittal and vertical patterns and was more projected in Class III and less projected in a high mandibular plane angle. A difference between younger and older adults was also detected in the chin soft tissue. With age, a mean increase of 1.3 mm in younger and 1.7 mm in older adults could be found for Pog', Gn' and Me' regions (Table 3).

Table 3: Alveolar, basal, and soft tissue in different sagittal and vertical patterns, age, and sex groups.

	Sagittal pattern (n=195)			Vertical pattern (n=195)			Age (years) (n=193)			Sex (n=195)		
	Class I (n=60)	Class II (n=64)	Class III (n=71)	Low MP (n=66)	Medium MP (n=62)	High MP (n=67)	>25 (n=89)	25-34,9 (n=49)	≥35 (n=50)	Male (n=100)	Female (n=95)	P- value
Alveolar symphysis												
IMPA (degrees)	95.0 (6.4)^{A}	103.9 (8.9)^{B}	83.8 (7.6)^{C}	97.0 (12.0)^{A}	94.3 (11.8)^{B}	90.0 (9.4)^{C}	95.8 (11.07)^{A}	93.4 (12.7) ^{A}	92.4 (11.6) ^{A}	94.04 (11.5)	93.7 (11.3)	0.849
B-B" (mm)	6.9 (1.0)^{A}	7.1 (1.7)^{A}	5.9 (1.2)^{B}	7.2 (1.5)^{A}	6.6 (1.4)^{B}	5.9 (0.9)^{C}	6.7 (1.4)^{A}	6.7 (1.4)^{A}	6.2 (1.4)^{A}	6.8 (1.5)	6.4 (1.2)	0.219
I1-Me (mm)	41.8 (3.2)^{A}	42.8 (4.2)^{A}	42.1 (3.8)^{A}	40.7 (3.1)^{A}	42.1 (3.6)^{B}	44.0 (3.7)^{C}	41.6 (4.0)^{A}	42.1 (3.4)^{A}	42.1 (3.9)^{A}	44.1 (3.5)	40.3 (3.0)	< 0.001
Basal symphysis												
A1Me.MP (degrees)	71.3 (4.8)^{A}	74.8 (8.8)^{B}	69.7 (8.2)^{A}	72.9 (7.1)^{A}	72.6 (9.2)^{A}	70.1 (6.9)^{A}	72.3 (8.1)^{A}	71.4 (7.8)^{A}	72.2 (8.6)^{A}	71.2 (8.0)	72.5 (7.6)	0.178
Pog-Pog" (mm)	14.1 (2.0)^{A}	14.8 (2.2)^{A}	14.3 (1.8)^{A}	14.7 (2.2)^{A}	14.6 (2.1)^{A}	14.0 (1.2)^{A}	14.4 (1.9)^{A}	14.6 (1.8)^{A}	14.3 (2.2)^{A}	14.9 (1.9)	13.9 (2.0)	< 0.001
V-Gn (mm)	62.7 (8.1)^{A}	56.4 (9.4)^{B}	72.3 (9.2)^{C}	71.5 (9.0)^{A}	64.1 (9.2)^{B}	56.9 (10.1)^{C}	63.7 (9.3)^{A}	63.9 (11.8)^{A}	65.0 (12.2)^{A}	67.2 (10.5)	61.0 (11.0)	< 0.001
H-Gn (mm)	108.1 (8.2)^{A}	105.5 (14.1)^{A}	108.5 (9.5)^{A}	102.4 (7.8)^{A}	108.4 (14.0)^{B}	111.4 (8.4)^{C}	108.4 (15.5)^{A}	107.0 (8.2)^{AB}	105.1 (9.7)^{B}	111.4 (12.2)	103.1 (7.3)	< 0.001
Soft tissue chin												
G'perp-Pog' (mm)	-3.2 (7.1)^{A}	-8.6 (7.8)^{B}	7.1 (7.5)^{C}	4.4 (9.3)^{A}	-0.9 (9.1)^{B}	-7.0 (8.1)^{C}	-1.5 (9.1)^{A}	-1.1 (10.8)^{A}	0.2 (10.7)^{A}	-0.8 (9.8)	-1.6 (10.3)	0.480
Pog-Pog' (mm)	11.8 (2.1)^{A}	12.8 (2.5)^{B}	12.4 (2.5)^{AB}	12.5 (2.8)^{A}	12.3 (2.4)^{A}	12.3 (2.00)^{A}	12.0 (2.3)^{A}	11.8 (2.4)^{AB}	13.3 (2.3)^{B}	12.9 (2.6)	11.8 (2.0)	0.002
Gn-Gn' (mm)	9.6 (2.4)^{A}	10.5 (2.8)^{A}	10.6 (2.9)^{A}	11.0 (3.0)^{A}	10.4 (2.6)^{A}	9.4 (2.4)^{B}	8.9 (2.3)^{A}	9.6 (2.0)^{A}	11.6 (2.8)^{B}	10.8 (2.8)	9.7 (2.5)	0.006
Me-Me' (mm)	8.3 (2.0)^{A}	8.4 (2.5)^{A}	9.0 (2.3)^{A}	8.5 (2.6)^{A}	8.7 (2.1)^{A}	8.4 (2.1)^{A}	8.3 (2.0)^{A}	8.1 (2.1)^{A}	9.1 (2.4)^{B}	9.3 (2.5)	7.8 (1.7)	<0.001

One-way ANOVA and t tests. Different letters represent statistical significance among groups and same letters, no statistical significance.

CORRELATION AND MULTIPLE REGRESSION ANALYSIS

Tables 4 and 5 present the correlation and multiple regression analysis, respectively. Dentoalveolar symphyseal morphology exerted different influences in terms of inclination, thickness and total height. The main factor affecting alveolar inclination was sagittal discrepancy (*r*= 0.567), and the combination of sagittal and vertical patterns explained 71.1% of inclination variability. Alveolar thickness was explained in part by the vertical and sagittal patterns ($R^2 = 0.279$, $P = <0.001$). Regarding symphyseal height, the main contributing factors were sex ($r = 0.243$) and vertical patterns ($r = 0.149$), highlighting these factors in this measurement variability ($R^2 = 0.436$).

Table 4: Outcome variables (alveolar, basal, and soft tissue) correlated with predictor variables (horizontal and vertical discrepancies, sex, and age).

	ANB (Sagittal discrepancy)			MP-angle (Vertical discrepancy)			Sex[a]			Age (years)		
	B value (CI 95%)	r	P- value	B value (CI 95%)	r	P- value	B value (CI 95%)	r	P- value	B value (CI 95%)	r	P- value
Alveolar symphysis												
IMPA	1.85 (1.62/2.08)	0.567	< 0.001**	-0.47 (-0.72/ -0.23)	0.07	<0.001**	0.31 (-2.92/3.55)	0	0.849	-0.13 (-0.14/0.12)	0	0.853
B-B″	0.08 (0.04/0.12)	0.079	< 0.001**	-0.09 (-0.12/-0.06)	0.166	<0.001**	0.36 (-0.03/0.77)	0.017	0.073	-0.007 (-0.02/0.01)	0.003	0.439
I1-Me	0.07 (-0.04/0.19)	0.009	0.199	0.22 (0.15/0.30)	0.149	<0.001**	3.71 (2.78/4.64)	0.243	<0.001**	-0.006 (-0.05/0.03)	0	0.809
Basal symphysis												
A1Me. MP	0.51 (0.28/0.74)	0.092	< 0.001**	-0.24 (-0.41/-0.07)	0.04	0.005**	-1.2 (-3.5/0.93)	0.007	0.255	0.02 (-0.06/0.11)	0.002	0.585
Pog-Pog″	0.02 (-0.03/0.08)	0.003	0.447	-0.05 (-0.10/-0.01)	0.033	0.01**	1.02 (0.46/1.59)	0.063	<0.001**	0.001 (-0.02/0.02)	0	0.943
V-Gn	-1.54 (-1.80/-1.28)	0.41	< 0.001**	-1.03 (-1.23/-0.83)	0.351	<0.001**	6.19 (3.15/9.22)	0.077	<0.001**	0.00 (-0.13/0.13)	0	0.997
H-Gn	-0.17 (-0.50/0.16)	0.005	0.313	0.59 (0.36/0.82)	0.12	0.001**	8.26 (5.40/11.13)	0.143	<0.001**	-0.11 (-0.24/0.01)	0.016	0.07
Soft tissue chin												
G′perp-Pog′	-1.51 (-1.73/-1.29)	0.489	< 0.001**	-0.84 (-1.03/-0.65)	0.285	<0.001**	0.77 (-2.06/3.62)	0.001	0.591	0.02 (-0.09/0.14)	0.001	0.670
Pog-Pog′	0.03 (-0.04/0.10)	0.004	0.368	-0.02 (-0.07/0.03)	0.003	0.467	1.09 (0.42/1.76)	0.051	0.001**	0.03 (0.008/0.06)	0.032	0.013*
Gn-Gn′	-0.02 (-0.11/0.05)	0.002	0.541	-0.11 (-0.17/-0.53)	0.068	<0.001**	1.11 (0.35/1.88)	0.041	0.004**	0.06 (0.02/0.09)	0.068	<0.001**
Me-Me′	-0.04 (-0.11/0.02)	0.007	0.246	0.01 (-0.04/0.06)	0.001	0.700	1.51 (0.90/2.12)	0.111	<0.001**	0.02 (-0.003/0.05)	0.016	0.08

Pearson correlation analysis.

[a] Female = 1 and male = 2; CI= confidence interval, P < 0.05 ** P < 0.01.

Table 5: Interaction models of horizontal pattern (ANB), vertical pattern (MP Angle), sex, and age using multiple regression model for predicting alveolar, basal and soft tissue.

	ANB vs MP Angle		ANB vs Sex		ANB vs Age		MP Angle vs Sex		MP Angle vs Age		Sex vs Age		ANB vs MP Angle vs Sex vs age	
Measurements	R^2	P	R^2	P	R^2	P	R^2	P	R^2	P	R^2	P	R^2	P
Alveolar symphysis														
IMPA	**0.711**	<0.001***	0.566	<0.001***	0.563	<0.001***	0.061	0.001**	0.061	0.001**	0.10	0.966	0.709	<0.001***
B-B"	**0.279**	<0.001***	0.091	<0.001***	0.073	<0.001***	0.164	0.007**	0.160	0.017**	0.002	0.456	0.283	<0.001***
I1-Me	0.142	<0.001***	0.250	<0.001***	0.001	0.426	0.436	<0.001***	0.141	<0.001***	0.235	0.152	**0.434**	<0.001***
Basal symphysis														
A1Me.MP	**0.144**	<0.001***	0.086	<0.001***	0.084	<0.001***	0.041	<0.001***	0.032	0.038*	0.009	0.002**	0.146	<0.001***
Pog-Pog"	0.030	0.019*	0.058	0.001**	0.007	0.747	**0.078**	<0.001***	0.024	<0.001***	0.054	<0.001***	0.077	0.001**
V-Gn	0.658	<0.001***	0.464	<0.001***	0.404	<0.001***	0.389	<0.001***	0.345	<0.001***	0.068	<0.001***	**0.692**	<0.001***
H-Gn	0.127	<0.001***	0.137	<0.001***	0.011	0.127	0.290	<0.001***	0.129	<0.001***	0.149	<0.001***	**0.312**	<0.001***
Soft tissue chin														
G´perp-Pog'	**0.673**	<0.001***	0.483	<0.001***	0.484	<0.001***	0.278	<0.001***	0.279	<0.001***	0.008	0.788	0.674	<0.001***
Pog-Pog'	0.002	0.455	0.047	0.004**	0.026	0.030*	0.042	0.006**	0.025	0.033*	0.075	<0.001***	**0.073**	0.001**
Gn-Gn'	0.058	<0.001***	0.032	0.016*	0.060	0.001**	0.089	<0.001***	0.130	<0.001***	0.102	<0.001***	**0.153**	<0.001***
Me-Me'	0.002	0.435	0.106	<0.001***	0.013	0.110	0.106	<0.001***	0.006	0.206	**0.119**	<0.001***	0.119	<0.001***

*P < 0.05. **P < 0.01. ***P < 0.001. Numbers in bold represent the highest result of interaction between two or all independent variables.

There was a weak association between basal symphyseal thickness (Pog-Pog") and the inclination of the basal symphysis (AL1Me.MP). However, sagittal position (V-Gn) interacted with the sagittal and vertical patterns, and explained almost 65% of the variability, in combination with the vertical pattern. The vertical position (H-Gn) was influenced by sex and vertical pattern, and explained 29% of vertical position variation.

The soft tissue position (G'perp-Pog') was mainly influenced by sagittal and vertical patterns, providing the main explanation for all variations (R^2= 0.673). Soft tissue thickness was weakly influenced by sex and age (Pog-Pog', R^2= 0.07; Gn-Gn', R^2 = 0.102; Me-Me', R^2 = 0.119).

DISCUSSION

Knowledge of the factors associated with the morphology of mandibular symphysis and adjacent tissues can be useful for planning genioplasty, which can be performed as an isolated procedure or as part of a more complex orthognathic surgery. To our knowledge, no previous study has explored the concept of symphysis morphology, including the surrounding tissues, using multiple regression analysis. This point allows to clarify the isolated and combined factors that can influence the morphology of the mandibular symphysis. This understanding may have a direct impact on clinical procedures, due to the possibility of reshaping only one type of tissue (skeletal or soft) or to modify both, considering sex and age. In general, the present study showed that the symphysis and soft tissue chin is a complex anatomical site influenced mostly by sagittal and vertical patterns, and complemented by sex and age, impacting differently on the alveolar, basal and soft tissue portions.

The present adult sample was well distributed in terms of sex and skeletal patterns and ranged from a balanced facial skeletal pattern to extreme discrepancies in the vertical and sagittal pattern. Such a miscellaneous sample is commonly researched to capture symphysis and surrounding tissue variations.[4,14,15]

Previous studies[11,16,18] have demonstrated that alveolar symphyseal inclination and thickness are influenced by sagittal and vertical skeletal patterns. These findings were also confirmed by the present results. For this reason, it was expected that vertical pattern could have a strong correlation with symphysis thickness, a fact not confirmed by the present results ($r = 0.166$). Another interesting data was that alveolar thickness maintained stable with aging. This study used a sample with patients ranging from 16 to 63 years old (most of them young adults). The older group showed a mean reduction of only 0.5 mm in the alveolar symphysis, and it was not considered statistically significant. Pre-surgical treatment in preparation for orthognathic surgery is a major clinical concern, especially in patients with Class III skeletal malocclusion and a hyperdivergent pattern. Forward orthodontic incisor inclination in a thin alveolar width could cause iatrogenic damage, such as dehiscence and fenestration, and could be associated with the development of gingival recession,[5,23] although a recent cohort study concluded that symphyseal morphology is not a risk factor for the occurrence of gingival recession.[24]

The position of the basal symphysis was naturally influenced by the sagittal and vertical skeletal patterns[11,16,18]. Gomez et al.[17] found that symphysis morphology measurements do not show significant relationships between skeletal pattern or between vertical patterns independently, but relationships are found when both parameters are associated, such as basal symphyseal inclination. The present results also showed an association of sagittal and vertical skeletal patterns in basal symphyseal inclination, but weak association with thickness. Basal symphyseal inclination was similar in skeletal Classes I and III, and in low and high mandibular plane angles. The basal lingual inclination detected in another study[12] on Class III mandibular symphysis was not corroborated by the present findings. Their study used a different methodology, in which basal inclination was influenced by mandibular incisor inclination. On the other hand, basal symphyseal thickness was not influenced by the studied variables and seemed to vary individually due to strong genetic determination. This data must be well explored in future studies, searching for specific genes that may contribute for the symphysis morphology.

In general, male anatomical dimensions and symphyseal linear measures are larger than those of females. Thickness, anteroposterior, and vertical positions, and various soft tissue measurements were greater in males, which is in accordance with previous studies.[4,18,20,23] However, no sex difference was found in the soft tissue chin projection, as previously demonstrated in a sample of a balanced face,[11] and could be explained by Enlow's hypothesis of growth equivalence.[24] Symphyseal height is, on average, 10% greater in males than in females, in both balanced and unbalanced faces, as shown by the present sample, and this result is in agreement with Gomez et al.[17] This feature also includes the height of the incisor crown.

Chin soft tissue was influenced by sex and age, even in adulthood. The sagittal and vertical patterns can predict only the position, contrasting with previous studies on soft tissue chin thickness that have shown the influence of various patterns of mandibular divergence and sex.[4,14] When age groups are compared, the present results corroborate findings that soft tissue thickness could increase with aging. This fact has already been observed longitudinally in individuals during growth.[18] A previous study showed that the soft tissue increased nearly 2mm between the ages of 6 and 18 years old.[25] The present results showed that Gn' thickness increased 1.7mm during adulthood, which was lower than in another study[19] that found a 3.7-mm increase over a 40-year period, considering from late adolescence to late adulthood. Age was also related to shortness of vertical basal symphysis position in the present sample. One possible explanation for this finding could be physiological tooth wear throughout life, and its consequence for the vertical dimension of the face.[27] Thus, longitudinal studies in adults should be encouraged to detect individual, sex, sagittal and vertical pattern variations over time, as age seems to be an influencing factor for both the vertical position of the symphysis and soft tissue thickness. This information could help facial surgeons on planning surgical interventions, and also inform surgical patients about the physiological changes throughout life.

This study has limitation regarding the cross-sectional design. Because the study was not based on a longitudinal data set, the association established needs to be carefully interpreted. However, the sample groups were allocated with comparable distribution, and also statistical adjustment contributed towards minimizing bias and confounding effects. In addition, the 2-D cephalometric measurements confirmed satisfactory reproducibility. Although 3-D evaluation is the current approach in skeletal researches, it is not recommended for all patients in orthodontics.[28,29] For ethical reasons and ALARA principle, the 3-D tomographic images must balance the risks and benefits, especially in patient with no treatment need (normal occlusion).[28,29]

Genioplasty can be designed to increase or reduce chin size or to straighten an asymmetrical chin. Although the response of soft tissues is similar to bone movement, genioplasty should be performed with discretion and individually (Fig 3). Two of the influence factors, such as age and sex, cannot be manipulated clinically, and together have influence on symphysis height and soft tissues thickness. The aging influence in each gender must be useful on the treatment planning of genioplasty.

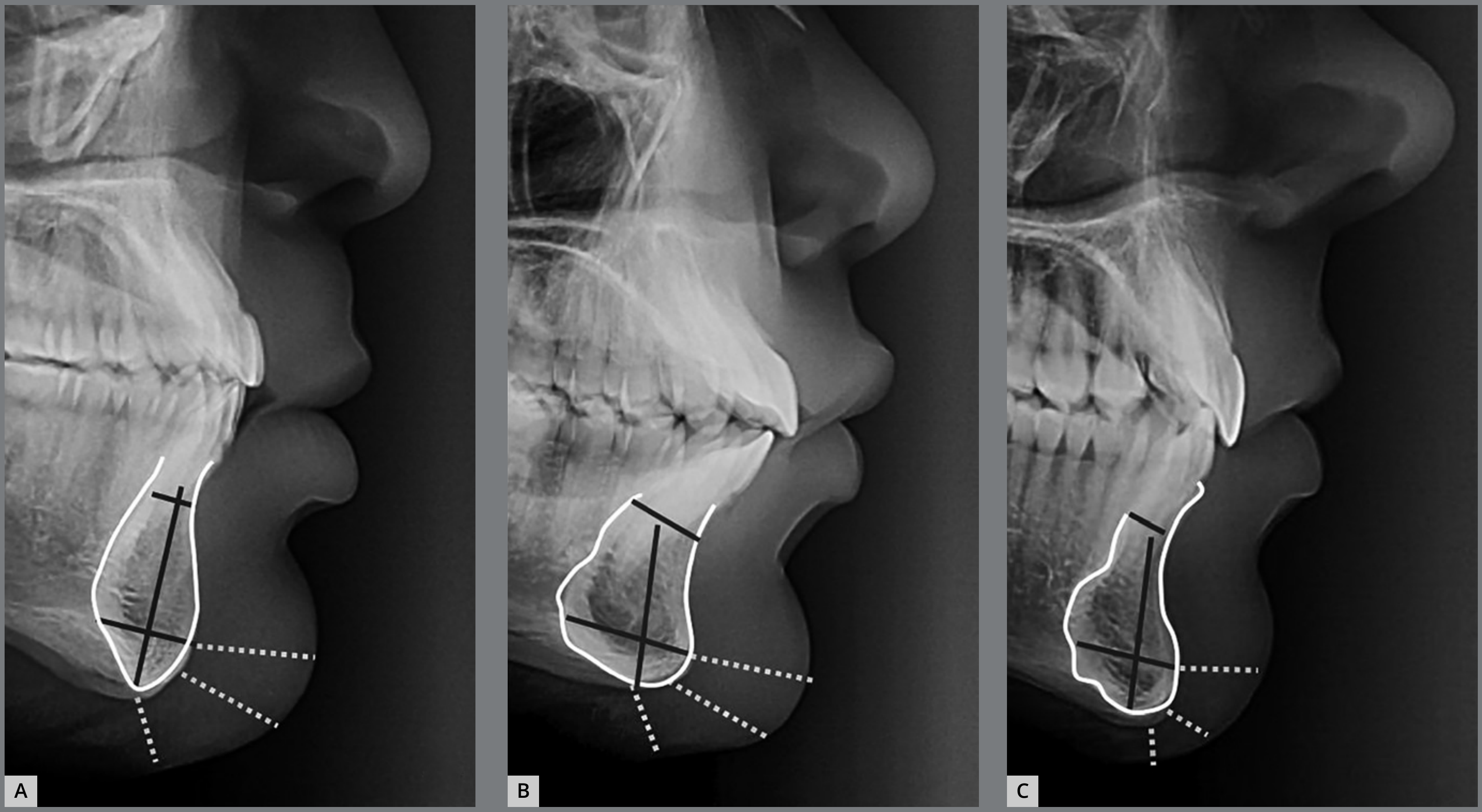

Figure 3: Variation in the morphology and dimension of the symphysis and surrounding tissues. **A)** Tall and narrow; **B)** Short and wide; **C)** Wide in the basal portion and narrow in the alveolar. No prediction of soft tissue chin can be estimated from the skeletal dimensions.

Older patients must have compensations about the probable shortening of the vertical height of the chin. The clinician must plan which tissue must be transformed (skeletal, soft tissue or both) in order to reach the best result on vertical position of the chin, also considering relapse of soft tissues in older patients. Additionally, since the morphology and position of the soft tissues can be altered by aging, it is essential to future studies to investigate predictive criteria for changes from hard to soft tissues, and apply this information not only after surgery but also in long term periods. The present study reinforces that the thickness of soft tissue chin is not necessarily related to the size of the underling skeletal pattern and, in addition, the influence of sex and age cannot be disregarded.

CONCLUSIONS

This study concludes that the morphology of symphysis and surrounding tissues are influenced by sex, age, and sagittal and vertical patterns variables, which acts differently in its alveolar, basal, and soft tissue portions. Sagittal and vertical patterns had the strongest association on alveolar symphysis inclination and soft tissue horizontal position. Sex and age can influence the basal symphysis position and soft tissues thickness. The varied morphologies corroborate the need for a strictly individualized planning of genioplasty.

AUTHORS CONTRIBUTIONS

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Conception or design of the study:
KE, JVN.

Data acquisition, analysis or interpretation:
KE, MAGS, DN, JVN.

Writing the article:
KE, MAGS, DN, JVN.

Critical revision of the article:
KE, MAGS, DN, JVN.

Final approval of the article:
KE, MAGS, DN, JVN.

Fundraising:
KE.

Overall responsibility:
MAGS, DN, JVN.

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

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Cephalometric evaluation of changes in vertical dimension and molar position in adult non-extraction treatment with clear aligners and traditional fixed appliances

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ABSTRACT

Introduction: Orthodontists have been using clear aligners to treat malocclusions, and one potential effect of treatment with orthodontic aligners is the intrusion and/or resists extrusion of the posterior teeth. This "bite-block effect" is primarily anecdotal due to the frequent occurrence of posterior open bites in patients after clear aligner therapy. **Objective:** The purpose of this study was to compare changes promoted by clear aligners and traditional fixed appliances in cephalometric measurements of the vertical dimension and molar position in adult patients with Class I malocclusion treated with non-extraction. **Methods:** Pre- and post-treatment lateral cephalometric radiographs of adult patients treated with either clear aligners (n=44) or traditional fixed appliances (n=22) were selected for retrospective analysis. Eight interval measurements and one nominal measurement were evaluated: anterior overbite (OB), mandibular plane angle related to cranial base (SN_MP) and related to Frankfort (FMA), lower molar height (L6H) and upper molar height (U6H), palatal plane to mandibular plane angle (PP_MP), lower facial height (LFH), total facial height (TFH), and posterior open bite (Posterior_OB). A single evaluator traced all cephalographs, and changes in select measures of the vertical dimension were compared within and between groups. **Results:** OB decreased (1.15 mm) and L6H increased (0.63 mm) in the traditional fixed appliance group. Mandibular plane angles (related to cranial base and to Frankfort) increased (0.43° and 0.53°, respectively) in the clear aligner group, but just FMA showed significant difference between groups (difference of 0.53°). LFH and TFH increased (ranging from 0.52 mm to 0.80 mm) in both groups, with no differences between treatment modality. Presence of visible posterior open bite significantly increased over the course of treatment. OB, FMA and L6H exhibited an interaction between treatment stage (pre- and post-treatment) and modality (clear aligner therapy and traditional fixed appliances), but no interaction among these three variables was found. **Conclusions:** The evidence does not support the theory that clear aligner therapy produces better vertical dimension control than traditional fixed appliances. Traditional fixed appliance therapy slightly extruded the lower molar, and clear aligner therapy produced a slightly mandibular backward rotation.

Keywords: Clear aligner. Traditional fixed appliance. Vertical dimension. Molar height.

RESUMO

Introdução: Ortodontistas têm usado os alinhadores transparentes para tratar más oclusões, e um potencial efeito desse tratamento é a intrusão e/ou resistência à extrusão dos dentes posteriores. Esse efeito de "bloco de mordida" é principalmente empírico, devido à ocorrência frequente de mordidas abertas posteriores em pacientes após a terapia com alinhadores transparentes. **Objetivo:** O objetivo do presente estudo foi comparar as mudanças promovidas pelos alinhadores transparentes e aparelho fixo convencional nas medidas cefalométricas de dimensão vertical e posição do molar em pacientes adultos com má oclusão de Classe I tratados sem exodontias. **Métodos:** Radiografias cefalométricas laterais pré- e pós-tratamento de pacientes adultos tratados com alinhadores transparentes (n=44) ou com aparelho fixo tradicional (n=22) foram selecionadas para uma análise retrospectiva. Oito medidas de intervalo e uma medida nominal foram avaliadas: trespasse vertical anterior (OB), ângulo do plano mandibular em relação à base do crânio (SN_MP) e em relação ao Plano de Frankfurt (FMA), altura do molar inferior (L6H) e altura do molar superior (U6H), ângulo do plano palatal ao plano mandibular (PP_MP), altura facial inferior (LFH), altura facial total (TFH) e mordida aberta posterior (Posterior_OB). Um único avaliador fez todos os traçados cefalométricos, e as mudanças nas medidas da dimensão vertical foram comparadas intra e intergrupos. **Resultados:** OB reduziu (1,15 mm) e L6H aumentou (0,63 mm) no grupo de aparelho fixo tradicional. Os ângulos do plano mandibular (em relação à base do crânio e ao plano de Frankfurt) aumentaram (0,43° e 0,53°, respectivamente). No grupo dos alinhadores invisíveis, apenas o FMA apresentou diferença significativa entre os grupos (diferença de 0,53°). LFH e TFH aumentaram (variando de 0,52 mm a 0,80 mm) em ambos os grupos, sem diferenças entre as modalidades de tratamento. A presença de uma mordida aberta posterior visível aumentou significativamente durante o curso do tratamento. OB, FMA e L6H exibiram interação entre o estágio do tratamento (pré- e pós-tratamento) e a modalidade (terapia com alinhadores invisíveis ou aparelho fixo tradicional), porém não foi encontrada interação entre essas três variáveis. **Conclusões:** A evidência não suporta a teoria de que a terapia com alinhadores invisíveis produz melhor controle da dimensão vertical do que o aparelho fixo. O tratamento com aparelhagem fixa extruiu ligeiramente o molar inferior, e o tratamento com alinhadores invisíveis produziu uma ligeira rotação posterior da mandíbula.

Palavras-chave: Alinhador transparente. Aparelho fixo tradicional. Dimensão vertical. Altura do molar.

INTRODUCTION

Orthodontists have traditionally focused on anteroposterior dentoskeletal relationships, but many malocclusions are due to abnormal vertical development. Vertical control during orthodontic treatment has been a challenging problem in orthodontics.[1,2] Therefore, it is often an objective to maintain or decrease vertical dimension in orthodontic patients, especially in hyperdivergent partients.[1,3] Successful treatment depends on the orthodontist's ability to control vertical tooth movements, because the extrusion of the posterior teeth is the main etiology of the unwanted side effects, such as backward mandibular rotation.[1,4]

In the past, orthodontists have traditionally addressed the vertical dimension of patients with high-pull headgear, both with and without extractions, but this approach appears to have little or no effect on the anteroposterior position of the mandible.[5-7] Today, some orthodontists may even attempt to reduce the mandibular plane angle, producing forward mandibular rotation using miniplates[8] and miniscrews.[1] Orthodontists know that fixed appliance therapy tends to extrude teeth, increasing the mandibular plane angle.[3]

Recently, orthodontists have been using clear aligners to treat malocclusions due to esthetics, convenience, and comfort.[9,10] Additionally, as the materials and techniques advance, more cases can be adequately treated with aligners.[11-13] One potential effect of treatment with orthodontic aligners is the "bite-block effect". In theory, the thickness of the aligner plastic combined with occlusal forces leads to intrusion and/or resists extrusion of the posterior teeth over the course of treatment. Evidence for this "bite-block effect" is primarily anecdotal and substantiated by the frequent occurrence of posterior open bites in patients after clear aligner therapy.[11,14,15] Some practitioners even recommend clear aligner therapy for patients who present with anterior open bite tendency, due to this alleged benefit.[16,17] As demand for clear aligner therapy increases, it is imperative for the orthodontist to understand how they act on the oral system.

Both traditional fixed appliances and clear aligners work by applying forces to teeth. Despite utilizing the same principles, there are many differences between the treatment modalities. A key difference is the ability to remove orthodontic aligners, which makes patient compliance imperative. Another significant difference is the appliance design. Aligners are polymer trays that fit snugly around the teeth, allowing force application from various directions, as opposed to traditional braces, which act primarily through the bracket on the buccal surface.[18] This difference leads to a number of advantages (e.g. patient comfort) [10] and disadvantages (e.g. limitations in amount of movement per aligner) associated with clear aligner therapy.[11]

It is important to investigate these claims and understand exactly how clear aligner therapy affects the vertical dimension in adult patients (the primary population requesting aligner therapy). If clear aligner therapy does limit changes in the vertical dimension or provides true intrusion, it could become a valuable treatment tool. However, if intrusion is not occurring, then the familiar post-treatment posterior open bite is due to other occurrences such as anterior interferences. It is the responsibility of orthodontists to understand the effects of their appliances, to provide the highest quality treatment results.

The aim of this longitudinal retrospective study is to compare changes in cephalometric measurements that represent the vertical dimension and molar position, before and after treatment in adult patients with Class I malocclusion treated with non-extraction, single-phase comprehensive treatment using clear aligners (Align Technology, Santa Clara, CA, USA) and traditional fixed edgewise appliances (Forestadent, Pforzheim, Germany). The null hypothesis was that there are no differences between treated groups.

MATERIAL AND METHODS

SAMPLE SELECTION

This observational retrospective, longitudinal, study used pre- and post-treatment lateral cephalometric radiographs from a sample of patients treated in a private practice, in Seguin, Texas. All patients were treated by the same orthodontist, and they were offered two modalities of treatment, clear aligner and traditional fixed appliance, according to the orthodontist office's policy. Patients were chosen based on the following inclusion criteria: Class I malocclusion, non-growing (18 years of age or older and cervical vertebral maturation stage V at beginning of treatment), mild to moderate crowding (6 mm or less per arch), no planned molar intrusion or extrusion (vertical movement of the molars in the final accepted ClinCheck was set and maintained at 0.0 mm for the entire series of aligners). Deep bite and crowding were treated using relative intrusion (proclination of the incisors) and interproximal reduction. Patients were excluded if they presented with the following criteria: congenital syndromes, crowding requiring extractions, and missing teeth other than third molars. In addition, radiographs that were not of diagnostic quality (i.e. improper patient positioning or lacking a ruler for calibration) were not utilized. Based on these parameters, 44 patients treated with clear aligners (27 females and 17 males, averaging 41.26 ± 14.59 years of age) and 22 patients treated with traditional fixed appliances (16 females and 6 males, averaging 32.01 ± 11.81 years of age) were identified. All patients had completed treatment within 2 years of May 2019.

CEPHALOMETRIC ANALYSIS

Standard lateral cephalometric radiographs of the selected patients were recorded at two stages: pre-orthodontic treatment (T_1) and immediately after orthodontic treatment (T_2). The traditional fixed appliances (brackets) patients were treated with bi-dimensional 0.018 x 0.022-in Edgewise brackets. The clear aligner patients were treated with Invisalign. Participants were monitored every 6-8 weeks.

The pre- and post-treatment lateral cephalograms were traced according to the American Board of Orthodontists (ABO guidelines[19] using Quick Ceph Software (Quick Ceph Systems, Inc., San Diego, CA) by one of the authors, who was blinded to the treatment stage and modality. A ruler positioned in each radiograph was used to adjust image size. The evaluator also superimposed each subject's records to ensure accurate tracing and magnification adjustments. Eight vertical measures (Table 1) were recorded for each lateral cephalogram (Fig 1): overbite (OB), sella-nasion to mandibular plane angle (SN_MP), Frankfort to mandibular plane angle (FMA), lower molar height (L6H), upper molar height (U6H), palatal plane to mandibular plane (PP_MP), lower facial height (LFH), and total anterior facial height (TFH). The evaluator also recorded whether posterior open bites [posterior_OB (visible space between the posterior teeth)] were seen on each lateral cephalogram (Fig 2). The posterior_OB was described as yes or no (lack of occlusal contact between maxillary and mandibular molars or contact between maxillary and mandibular molars, respectively).

Table 1: Definition of measurements.

Overbite (OB)	Distance (mm) measured from incisal edge of the most anterior upper central incisor (U1) to incisal edge of the most anterior lower central incisor (L1).
Sella-Nasion to Mandibular Plane Angle (SN_MP)	Angle (degrees) measured between sella-nasion (SN) plane and mandibular plane (Go-Me).
Frankfort to Mandibular Plane Angle (FMA)	Angle (degrees) measured between Frankfort Horizontal (Po-Or) and mandibular plane (Go-Me).
Lower Molar Height (L6H)	Distance (mm) measured perpendicular of line from mandibular plane (Go-Me) to mesial-buccal (MB) cusp of lower first molar (L6).
Upper Molar Height (U6H)	Distance (mm) measured perpendicular of line from palatal plane (ANS-PNS) to mesial-buccal (MB) cusp of the upper first molar (U6).
Palatal Plane to Mandibular Plane Angle (PP_MP)	Angle (degrees) measured between palatal plane (ANS-PNS) and mandibular plane (Go-Me).
Lower Facial Height (LFH)	Distance (mm) measured from anterior nasal spine to menton.
Total Anterior Facial Height (TFH)	Distance (mm) measured from nasion to menton.

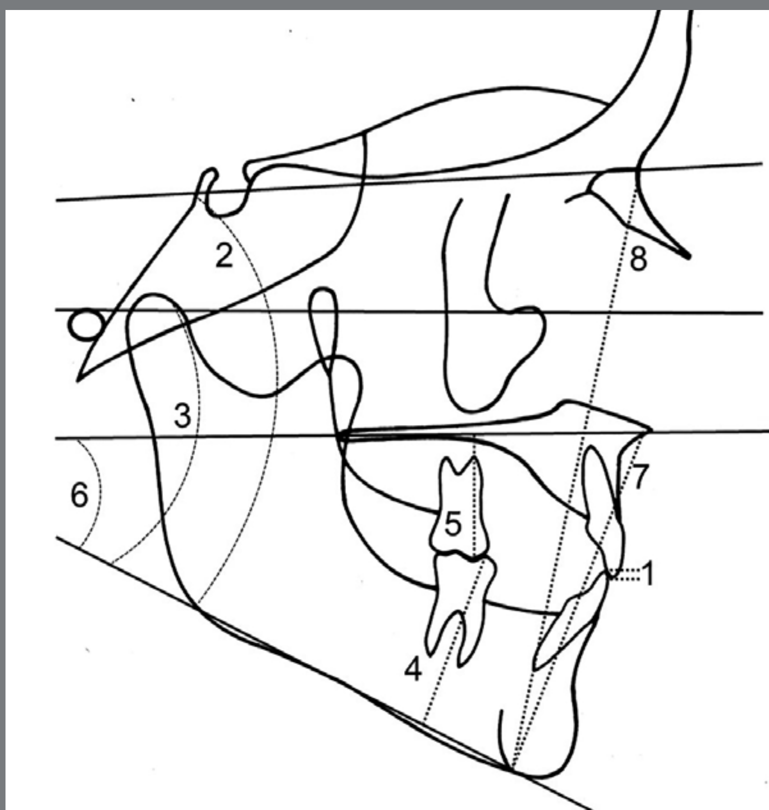

Figure 1: Cephalometric measurements evaluated: 1) OB; 2) SN_MP; 3) FMA; 4) L6H; 5) U6H; 6) PP_MPA; 7) LFH; 8) TFH.

Figure 2: Lateral cephalometric radiograph showing a patient presenting a posterior open bite (lack of posterior occlusal contact).

STATISTICAL ANALYSIS

The evaluator randomly selected and retraced 10 sets of records (5 clear aligner and 5 traditional fixed appliance subjects) one month after the initial measurements were recorded. Intraobserver systematic errors between the replicate scans were described as mean differences and statistically compared with paired t-tests. Intraobserver random error was estimated using intraclass correlation coefficients (ICCs) and method errors ($\sqrt{(\Sigma d^2/2n)}$).[20] Sample size calculations were not performed prior to the study.

The measurements were transferred to SPSS software (version 25.0, IBM SPSS Statistics, Armonk, NY, USA). Based on the skewness and kurtosis statistics, the variables were judged normally distributed. Paired *t*-tests were used to evaluate changes over time (i.e., differences between pre-treatment and post-treatment). T-tests were used to compare the groups. Box plots were used to characterize the sample using the 25^{th}, 50^{th} and 75^{th} percentiles, as well median, whiskers, and outliers. Effect size was calculated using Cohen's *d*. Linear mixed models were run to identify the effects of treatment modality (clear aligners and traditional fixed appliances) and treatment stage (pre- or post-treatment), and interaction effects of modality and stage on each measured variable. A probability level of 0.05 was used to determine statistical significance.

RESULTS

Systematic intraobserver reliability ranged between 0.02 mm and -1.01 mm (Table 2). Five out of eight measurements (presence of posterior open bite was identical between both replicates and therefore not included) were statistically significant (Table 2). L6H showed the largest significant difference between the first and second replicates, with the first replicate 1.01 mm less than the second replicate. Mandibular plane related to cranial base (SN_MP) and to Frankfort (FMA), and palatal plane (PP_MP) also showed the first replicate smaller than the second replicate (0.17°, 0.28°, and 0.34°, respectively). The first replicate of OB was

Table 2: Intraobserver systematic errors between replicates (first minus second) for each of the measurements, along with significances (Sig) and Intraobserver random errors between replicates, estimated with method errors (ME) and interclass correlations (ICC). Bold font indicates statistically significant difference.

Variable	Difference	S.D.	Sig.	M.E.	ICC
OB (mm)	0.16	0.20	**0.001**	0.25	0.985
SNMP (degrees)	-0.17	0.32	**0.024**	0.36	0.999
FMA (degrees)	-0.28	0.37	**0.002**	0.46	0.999
PPMP (degrees)	-0.34	0.38	**0.001**	0.50	0.999
L6H (mm)	-1.01	0.53	**< 0.001**	1.14	0.978
U6H (mm)	-0.25	0.21	0.596	0.20	0.998
LFH (mm)	0.02	0.27	0.685	0.27	0.999
TFH (mm)	0.09	0.28	0.173	0.29	0.999

larger than the second replicate (0.16 mm). Method error ranged from 0.25 mm to 1.14 mm and from 0.35° to 1.58° (Table 2). All measurements showed highly reliable interclass correlation (ICC), ranging from 0.978 to 1.000 (Table 2). Intraobserver errors were deemed to be within an acceptable range.

Invisalign group presented older patients than brackets group (*p* = 0.012). Prior to treatment, four out of the 44 clear aligner (Invisalign) patients and one out of the 22 traditional fixed appliances (brackets) patients exhibited posterior open bites on their lateral cephalographs. At the completion of treatment, 7 (31.82%) traditional fixed patients and 17 (38.64%) of the clear aligner patients exhibited a posterior open bite. Regarding the overbite, approximately 75% of the subjects in each group presented normal overbite prior to the treatment. Invisalign group presented two patients with anterior open bite (1.90 mm and 1.60 mm) and Brackets group had one (0.60 mm).

Statistical analysis showed significant difference between groups only for one out of eight variables measured (Table 3). In comparison to the Brackets group, the Invisalign group initially had larger lower molar height (≈2.0 mm). In general, Invisalign group showed slightly larger dispersion than Brackets group (Fig 3).

Table 3: Comparison of pretreatment values between subjects treated using clear aligners and subjects treated using conventional fixed appliances (brackets).

	Invisalign		Brackets		
Variables	Mean	SD	Mean	SD	Prob.
OB	2.33	1.84	2.71	1.90	.427
SN_MP	30.73	6.64	30.71	6.86	.990
FMA	22.65	5.72	23.42	5.70	.605
L6H	33.25	3.50	31.23	2.36	**.017**
U6H	23.32	2.32	23.15	2.22	.779
PP_MP	23.21	6.24	23.16	5.32	.977
LFH	65.40	6.06	63.15	5.48	.147
TFH	116.98	8.01	113.40	6.36	.073

Bold font indicates significant difference.

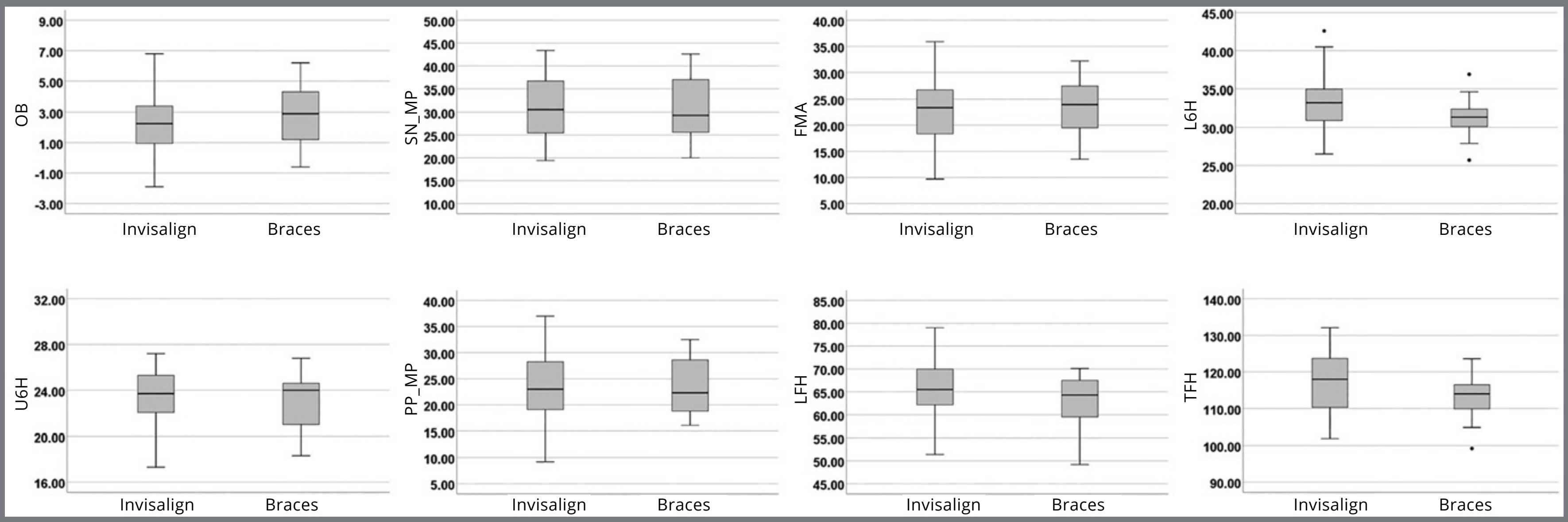

Figure 3: *Box plots* providing information about sample distribution, skew, and range of data for each of the eight measurements pretreatment. The upper and lower boundaries of the rectangle indicate the upper and lower quartiles, respectively. The line inside the rectangle indicates the median. The distance between the median and the quartile indicates the skew of the data. The whiskers extending from the box indicate the extreme values.

Regardless of pretreatment measures, both treatment modalities produced significant differences (Table 4). OB decreased in the Brackets group (1.15 mm) and remained unchanged in the Invisalign group (0.09 mm). SN_MP and FMA increased in the Invisalign group (0.43° and 0.53°, respectively) and remained the same in the Brackets group. Facial height increased in both groups. LFH increased 0.52 mm in the Invisalign group and 0.79 mm in the Brackets group. TFH increased from 116.98 mm to 117.78 mm (0.80 mm) in Invisalign patients, and from 113.40 mm to 114.14 mm (0.74 mm) in Brackets patients.

Treatment modality produced significant group change differences (Table 4). OB decreased more in the Brackets group than in the Invisalign group (1.06 mm). Relative to FMA, Invisalign patients showed greater backward rotation (0.53°). L6H increased more in the Brackets (0.63 mm) group than in the Invisalign group (0.17 mm). The Brackets group showed larger dispersion to OB changes, but in general, Invisalign group presented slightly larger amount of dispersion (Fig 4). Cohen's effect size value of d=0.7 for OB suggested medium-to-large practical significance with a power of 0.79. Other measurements showed medium or small effect size with the differences have small to negligible practical significance (with power of 0.75 or less).

Table 4: Comparison of changes in subjects treated using clear aligners and subjects treated using conventional fixed appliances (Brackets). Negative values indicate decreasing and positive values indicate increasing over time; difference was calculated using clear aligners minus conventional fixed appliances.

	Invisalign			Brackets			Invisalign vs. braces (diff.)		
Variables	Mean	SD	Prob.	Mean	SD	Prob.	Mean	SE	Prob.
OB	-0.09	1.09	0.584	-1.15	1.61	**0.003**	-1.06	0.38	**0.009**
SN_MP	0.43	1.07	**0.011**	0.01	0.82	0.959	0.42	0.26	0.113
FMA	0.53	1.02	**0.001**	-0.00	0.79	0.979	0.53	0.25	**0.038**
L6H	0.17	0.61	0.068	0.63	0.76	**0.001**	-0.46	0.17	**0.010**
U6H	0.06	0.70	0.578	-0.14	0.46	0.183	0.20	0.16	0.240
PP_MP	0.02	1.13	0.905	0.17	1.03	0.454	-0.15	0.29	0.609
LFH	0.52	0.93	**0.001**	0.79	0.85	**<0.001**	-0.27	0.24	0.261
TFH	0.80	0.99	**<0.001**	0.74	0.93	**0.001**	0.06	0.25	0.817

Bold font indicates significant difference.

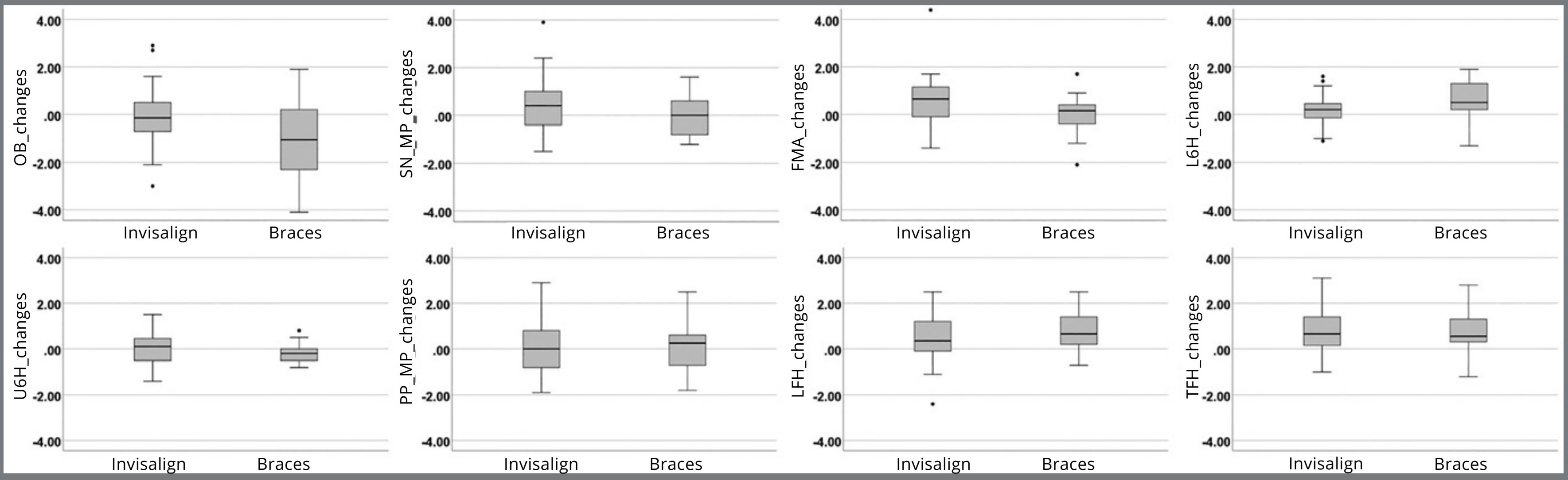

Figure 4: *Box plots* providing information about sample distribution, skew, and range of data for the changes due to orthodontic treatment of each of the eight measurements.

OB, FMA and L6H all exhibited a statistically significant interaction between treatment stage and treatment modality (Table 5 and Figure 5). Since L6H had a significant interaction between treatment modality over the course of treatment, and because extrusion is known to be more serious in high angle patients, an additional analysis was performed to see if SN_MP or FMA values affected L6H. This analysis found that there was no significant interaction between treatment, stage and SN_MP ($\chi^2 = 0.536$; $p = 0.464$) or between treatment, stage and FMA ($\chi^2 = 0.796$; $p = 0.372$) on L6H.

Table 5: Chi-squared test (χ^2) and probability (Prob.) of Linear Mixed Model Analysis.

Variables		Treatment (T)	Stage (S)	T:S
OB	χ^2	0.146	7.902	9.994
	Prob.	.703	**0.005**	**0.002**
SN_MP	χ^2	0.017	5.495	2.576
	Prob.	.897	**0.019**	0.109
FMA	χ^2	0.114	9.261	4.513
	Prob.	.736	0.002	**0.034**
L6H	χ^2	4.476	16.810	7.993
	Prob.	.034	**<0.001**	**0.005**
U6H	χ^2	0.210	0.006	1.405
	Prob.	.647	0.938	0.236
PP_MP	χ^2	<.001	0.265	0.265
	Prob.	.986	0.607	0.607
LFH	χ^2	1.940	29.740	1.288
	Prob.	.168	**<0.001**	0.257
TFH	χ^2	3.427	41.927	0.054
	Prob.	.064	<0.001	0.816
Posterior_OB	χ^2	0.567	11.503	0.104
	Prob.	.452	**<0.001**	0.747

Bold font indicates significant difference.

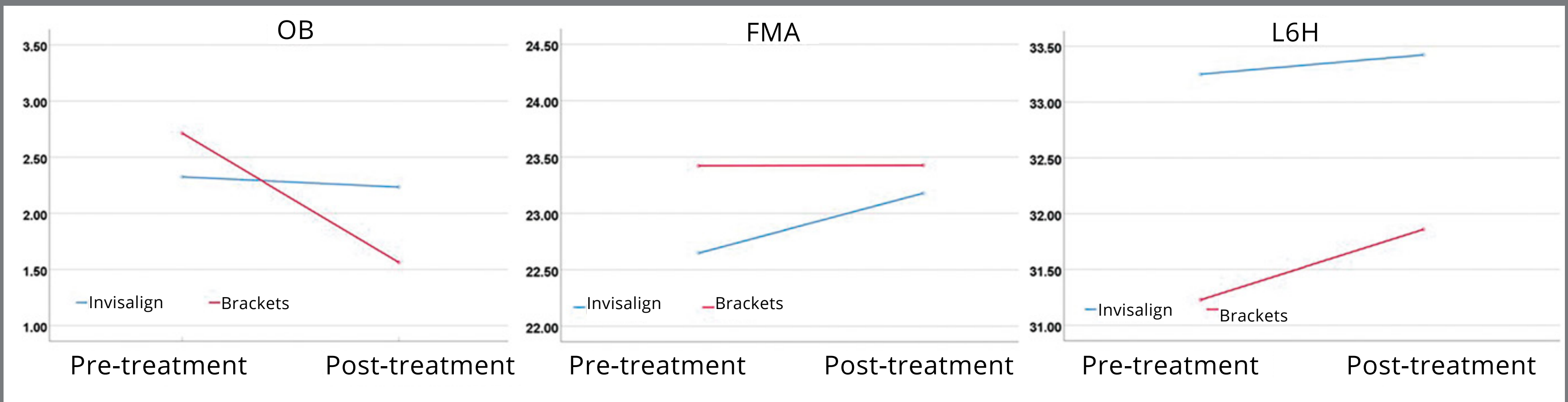

Figure 5: Linear mixed models identifying the effects of treatment modality (clear aligners and traditional fixed appliances) and treatment stage (pre- or post-treatment) on OB, FMA, and L6H.

DISCUSSION

Vertical control of both the maxillary and mandible molars is important to control the vertical dimension in patients. Although clear aligners and traditional fixed appliances showed a good clinical vertical control of the maxillary molars, traditional fixed appliances showed slightly larger lower molar extrusion, compared to clear aligners (approximately 0.5 mm). U6H likely experienced minimal change because it is less commonly subjected to extrusive mechanics, such as elastics, than the lower molar. The lack of statistically significant change in these variables indicates that both treatment modalities are adequate at preventing excessive maxillary molar extrusion and bite opening. The slightly larger amount of extrusion of the lower molars can be observed as a side effect of elastics in the traditional fixed appliance group, and it agrees with the idea that Invisalign does not apply extrusive forces unless they are prescribed in the ClinCheck. Comparing clear aligners to fixed appliances, Garnett et al.[21] showed also a good vertical control of the mandibular molars, with no significant difference between groups; but the authors reported the use of various auxiliaries such as lower lingual holding arches and miniscrews to treat anterior open bites. Analyzing only patients presenting open bite treated with clear aligners, Moshiri et al.[16] showed a slightly intrusion of the mandibular molars by 0.6 mm. Comparisons are problematic because of differences in the design of the studies.

Anterior overbite decreased in traditional fixed patients and did not change due to treatment in the clear aligner patients. Buccal-lingual movement of the incisors can influence the overbite due to relative intrusion/extrusion. Patients with deeper bites or more crowding require more flaring or interproximal reduction (IPR) to align the teeth. While not a primary measure of this study, interincisor angle decreased significantly (3.44°) in the clear aligner group and did not change in the traditional fixed appliance group (6.69°). This observation could be due to treatment plan and/or patient selection; several patients treated with clear aligner therapy received interproximal reduction, allowing a better control of the incisor proclination. Studies have shown no differences related to overbite, maxillary incisor angulation, mandible incisor angulation, and interincisor angle between clear aligners and fixed appliances,[21] or decreasing open bite in patients treated with Invisalign.[16] In addition, Invisalign is reported to have difficulty achieving root torque,[11-13] that should provide controlled tipping.

Although anterior facial height and lower facial height increased in both treatment modalities at the same level (differences smaller than 0.30 mm), only the clear aligner group showed slightly backward rotation of the mandible (FMA). Therefore, it is difficult to claim clinical significance. Mandibular plane is vulnerable to tracing errors due to patient positioning, landmark identification errors, and bilateral structures, making it difficult to identify in a standardized way, and this could lead to the outcome reported. When clear aligner therapy and traditional fixed appliance therapy were compared in open bite treatment, the literature showed the same changes for mandibular plane (0.60°) and anterior lower facial height (0.36 mm) for patients treated with clear aligners and traditional fixed appliances.[21] Analyzing open bite treatment of patients under Invisalign therapy, Moshiri et al.[16] showed small decreasing of the lower anterior facial height (1.5°) and of the mandibular plane angle (0.9°).

Presence of a visible posterior open bite significantly increased over the course of treatment in both groups. A posterior open bite was seen more frequently in post-treatment radiographs, in both the clear align group and the traditional fixed appliance group. This phenomenon is likely due to anterior interferences keeping the posterior bite out of occlusion, since intrusion of the molars was not measured in the majority of the records. It should be expected that the areas of occlusal contact increase during retention phase.[22,23]

Out of the treatment variables selected, overbite, FMA and lower molar height exhibited significant interactions between treatment stage and treatment modality. This means that the changes in pre- and post-treatment values were dependent on the treatment method (Brackets or Invisalign). L6H was analyzed further by comparing the effect of the patient's SN_MP and FMA on its values. Analysis revealed that there was not an interaction between L6H values and the patient's SN_MP or FMA for either treatment group. In hyperdivergent patients, there is a greater desire to control molar extrusion to prevent the mandibular backward rotation.

This study is not without limitations. Although no vertical movement of the molars were planned, the proclination of the mandibular incisors through mechanics, such as reverse curve of Spee, could affect the vertical molar position. Information about treatment mechanics (i.e. elastic use) and treatment duration was not provided for each patient. This information could be correlated to certain changes observed over the course of treatment. There is significant risk for case selection bias in this retrospective analysis. Aligner therapy has become more popular with patients and clinicians, but fixed appliances are often reserved for adults with more complicated initial malocclusions. A prospective, randomized, controlled trial would be a beneficial follow-up study to support or refute the findings reported in this study comparing clear aligner therapy and traditional fixed appliance therapy. One should keep these limitations in mind and the results should be carefully interpreted, and the generalization of the results may be limited.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1. Anterior overbite decreased more in the traditional fixed appliance therapy than clear aligner therapy.
2. Traditional fixed appliance therapy promoted a slightly larger lower molar extrusion than clear aligner therapy.
3. Clear aligner therapy produced slight mandibular backward rotation.
4. Both therapies (clear aligners and traditional appliances) increased the total facial height and lower facial height.
5. The clear aligner therapy did not provide a better vertical dimension control than traditional fixed appliance therapy adult patients.

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Data acquisition, analysis or interpretation:
HR, JE, CC, FKK, RG, HBJ.

Writing the article:
HR, JE, FKK, HBJ.

Critical revision of the article:
HR, JE, CC, FKK, RG, HBJ.

Final approval of the article:
HR, JE, CC, FKK, RG, HBJ.

Fundraising:
JE, CC.

Overall responsibility:
HBJ.

Patients displayed in this article previously approved the use of their facial and intraoral photographs.
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BBO'S SELECTED ARTICLE

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Orthodontic camouflage as a treatment alternative for skeletal Class III

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ABSTRACT

Introduction: Skeletal Class III malocclusion is a deformity of complex treatment, with few intervention alternatives, which are further limited in nongrowing patients. In most cases, orthognathic surgery is the ideal treatment for adults, an option often refused by patients. Mild to moderate skeletal Class III malocclusions and acceptable facial esthetics can benefit from a course of treatment in which dental movements are used to compensate for the skeletal discrepancy.

Objective: This study aimed to discuss orthodontic camouflage as an option for adult patients with Class III malocclusion, emphasizing its indications, implications and expected results.

Keywords: Class III malocclusion. Orthodontic camouflage. Dental compensation.

RESUMO

Introdução: A má oclusão esquelética de Classe III é uma deformidade de difícil tratamento e com poucas alternativas de intervenção, que ficam ainda mais limitadas em pacientes sem crescimento. Na maior parte dos casos, o tratamento ideal para adultos é a cirurgia ortognática, opção muitas vezes recusada pelo paciente. As más oclusões esqueléticas de Classe III leve a moderada e com estética facial aceitável podem se beneficiar de um plano de tratamento no qual movimentações dentárias são realizadas para compensar a discrepância esquelética. **Objetivo:** O objetivo do presente estudo foi discutir a camuflagem ortodôntica como opção para pacientes adultos com má oclusão de Classe III, ressaltando suas indicações, implicações e resultados esperados.

Palavras-chave: Classe III. Camuflagem ortodôntica. Compensação dentária.

INTRODUCTION

Skeletal Class III malocclusion is one of the most challenging problems faced by orthodontists.[1,2] It is characterized by an anteroposterior discrepancy between the maxilla and the mandible usually associated with dentoalveolar compensation (protruded maxillary incisors and/or proclined and retroclined mandibular incisors), to maintain the function and camouflage the existing skeletal discrepancy.[3] Compromised facial esthetics is often present, constituting, in these cases, the main reason why patients or their guardians seek treatment.[4]

In adult patients, treatment is more complex due to the limited options available.[5] In most cases, orthodontic treatment combined with orthognathic surgery is often the ideal treatment. However, many patients refuse the surgical option due to its cost or the invasive nature of the procedure.[6,7]

Nongrowing patients with mild to moderate skeletal Class III malocclusion and acceptable facial esthetics can benefit from camouflage orthodontic treatment,[3] to enable the displacing of teeth relative to their supporting bone to compensate for an underlying jaw discrepancy. It is indicated when growth modification to overcome the basic problem is not feasible.[1] The objectives of camouflage treatment include attaining acceptable occlusion, function, and esthetics through dentoalveolar compensation for the skeletal discrepancy.[8]

Camouflage treatment was introduced into orthodontics in the 1930s and 1940s, when extraction to camouflage a skeletal malocclusion became popular, as growth modification had been widely regarded as ineffective, and surgical correction was still in early development. The strategy to camouflage a Class III malocclusion usually involves proclination of the maxillary incisors and retroclination of the mandibular incisors, to improve dental occlusion, although it might not correct the skeletal problem or facial profile.[1]

In patients with moderate skeletal Class III malocclusion, the decision for orthodontic camouflage as a treatment option should consider some parameters. First, the extent of compromise of facial esthetics must be assessed and how important this is for the patient. In cases of significant esthetic complaint, orthognathic surgery is required.[9,10] The second parameter is the anteroposterior position and inclination of maxillary and mandibular incisors, and whether their orthodontic movement is sufficient for correcting the malocclusion. The third parameter is the thickness of mandibular symphysis, which should allow extensive incisor retraction. Finally, the degree of anteroposterior discrepancy must also be assessed. Even if facial esthetics is acceptable, the symphysis is thick enough, and the mandibular incisors are favorably inclined, camouflage will not be indicated if the anteroposterior discrepancy is too severe.[10,11]

The initial positioning of maxillary and mandibular anterior teeth, and mandibular growth are unfavorable for the nonsurgical treatment of Class III malocclusion. Maxillary incisors showing compensatory protrusion and mandibular incisors showing lingual inclinations are often observed, limiting the amount of negative overjet that could be treated without surgery.[13]

From this perspective, this study aimed to address orthodontic camouflage as an option for adult patients with skeletal Class III malocclusion, and describe the orthodontic treatment of a male patient with 19 years and 8 months, treated with dental compensations — this case was submitted to the Brazilian Board of Orthodontics (BBO).

CASE REPORT

A male patient (19 years and 8 months) in good general health sought orthodontic treatment with the complaint of being dissatisfied with the result obtained after eight years of treatment, dissatisfied with his smile, and bothered by the lower crowding. He also complained about not having the upper left canine (#23), lost during previous orthodontic treatment (resulting from eruption disturbance).

Facial examination revealed facial asymmetry and increased lower third of the face. Smile esthetics was damaged by posterior crossbite, which widened his buccal corridor. The facial profile was concave, with a slight deficiency in the middle third of the face and a good nasolabial angle. Intraoral clinical examination revealed that the patient, although without a history of carious lesions or dental restorations, presented poor oral hygiene. The patient had Angle's Class III malocclusion, more pronounced on the right side, with reduced overbite and overjet, and open bite in the region of teeth #12, #13, #22 and #24. Bilateral posterior crossbite was more extensive on the left side, and tooth #23 was missing, creating spaces and generating significant asymmetry in the maxillary arch. Moreover, according to his complaint, the patient showed a 10 mm mandibular crowding in the anterior and middle region, with retroclined mandibular incisors, compensating the Class III malocclusion, and marked gingival recession in tooth #33. Finally, there was a lack of space in the posterior region for the correct positioning of teeth #36 and #46.

Functional examination revealed the absence of lateral disocclusion, compromised by the missing #23, occasional TMJ clicking, slightly atypical swallowing and phonation, and mouth breathing (Figs 1 and 2). Initial lateral cephalometric radiograph revealed a sagittal maxillary deficiency (SNA = 76) and a clear Class III skeletal pattern, with ANB = 0. Moreover, vertical growth deficiency of the mandibular ramus and a vertical growth pattern (SN.GoGn = 43° and FMA = 31°) were observed, with compensatory inclination of the incisors (1.NA = 25°, 1.NB = 12° and IMPA = 70°) and a concave profile (NAPog = -2°) (Fig 3, Table 1).

TREATMENT PLAN AND MECHANICS USED

Since he was satisfied with his facial esthetics, the patient was contrary to any surgical intervention to treat the skeletal Class III malocclusion. Therefore, the chosen treatment was orthodontic camouflage, with the extraction of tooth #15 followed by the loss of upper anchorage and extraction of the first mandibular premolars, maintaining maximum anchorage for the retraction of the anterior teeth without modifying the positions of teeth #36 and #46.

Figure 1: Initial facial and intraoral photographs.

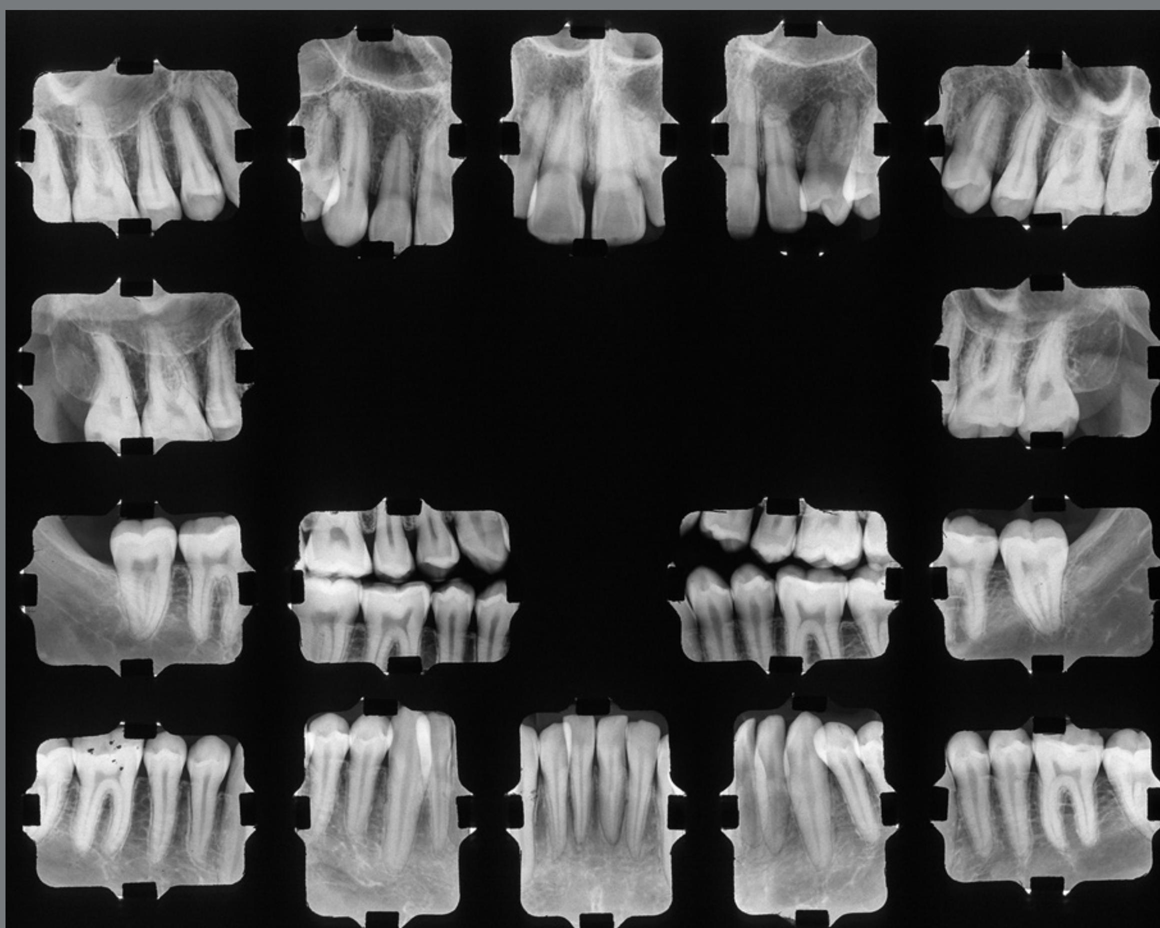

Figure 2: Initial periapical radiographs.

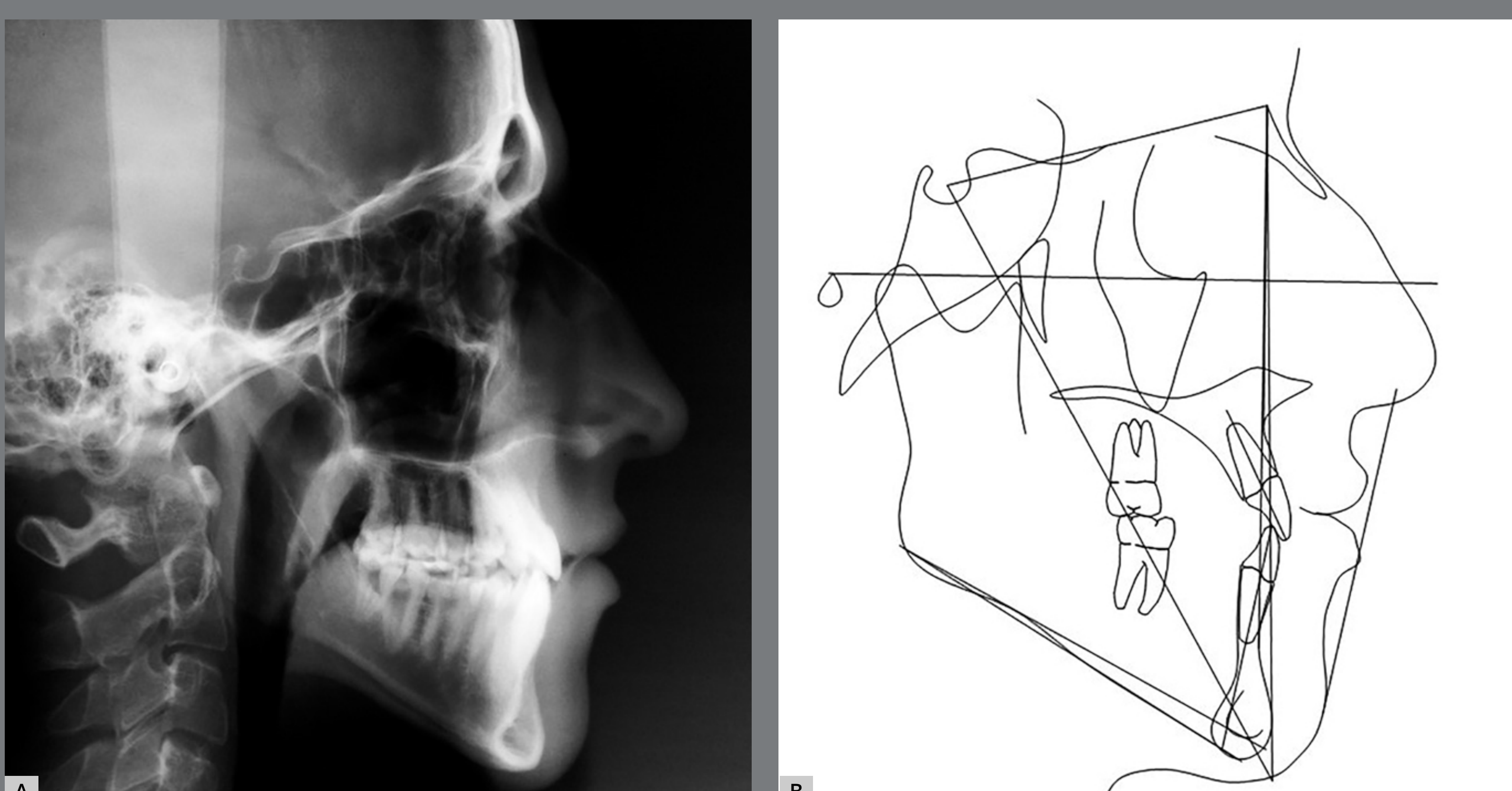

Figure 3: Initial cephalometric profile radiograph **(A)** and cephalometric tracing **(B)**.

The objectives of treatment included the improvement of oral hygiene, with health instructions and rigorous dental plaque control, to prevent the worsening of gingival recession in tooth #33. Profile harmonization in the lower third and negative discrepancy in the mandibular arch were favored by the extraction of the first premolars and retraction of the mandibular incisors, whereas the positive discrepancy and asymmetry in the maxillary arch was corrected by closing the spaces and with the extraction of tooth #15. The correction of the transverse problem caused by bilateral posterior crossbite by improving the shape of the maxillary arch was well planned, as well as the vertical control for improving or, at least, maintaining the existing counterclockwise rotation. The patient was referred to speech therapy and otorhinolaryngology services to correct slightly atypical swallowing and phonation habits and mouth breathing.

Treatment began by mounting a fixed standard edgewise appliance with 0.022 x 0.028-in slots. A lingual arch was placed in the mandibular arch as an anchorage resource, supported by the mandibular first molars. Next, the alignment and leveling phase was started. Stainless steel archwires from 0.014-in to 0.020-in were used in the mandibular arch, followed by 0.019 x 0.026-in archwire, loss of upper posterior anchorage with elastomeric chain, realignment, and a final 0.019 x 0.026-in archwire. In the mandibular arch, a 0.014-in archwire was used with a vertical loop mesial to the canines and a teardrop loop in the extraction space, using active tie-back, taking care not to procline the incisors. Treatment followed with a sequence of 0.016-in and 0.018-in contracted stainless steel archwires, starting the distalization of teeth #33 and #43 still in the 0.018-in archwire (passive) with elastomeric chain. At the end of canine retraction, incisor retraction began with the 0.019 x 0.026-in stainless steel coil spring retraction archwire. Finally, continuous 0.019 x 0.026-in archwire was used. As an auxiliary resource, Class III mechanics was used on the right side with intermaxillary elastics, in addition to complementary binary resources to achieve the translation movement. At the end of orthodontic tooth movement, an upper removable wraparound retainer was placed with vertical loops in the region of the canines (kept continuously for one year, and for another five years, just for sleeping), whereas, in the lower arch, a 3x3 fixed lingual retainer was placed (removed seven years later). After removing these appliances, no retention device was installed, and the patient was followed up annually.

TREATMENT RESULTS

The orthodontic treatment performed had its objectives achieved and provided functional and esthetic improvements. The deficiency of the middle third remained, as well as the facial asymmetry, but they remained discreet. The buccal corridor was shortened with the correction of bilateral posterior crossbite, making the smile more pleasant. The positioning of the lower lip was slightly modified, making the patient's profile more harmonious. The shape of the arches was improved, with the mandibular crowding and spaces in the maxillary arch being eliminated, achieving root parallelism and stability of the gingival recession of tooth #33. On the right side, a Class I relationship of molars and canines was reached. On the left side, a good relationship was obtained between teeth #33 and #24, and a good degree of overbite and overjet was obtained. Good root parallelism was achieved, and the gingival recession in tooth #33 was stabilized. The patient's skeletal pattern was preserved, and the objective of vertical control was achieved by maintaining the initial anticlockwise rotation (SN.GoGn = 43° and FMA = 29°). New dental compensations were required for orthodontic correction (1.NA = 24°, 1.NB = 6° and IMPA = 64°) and the initially concave profile was maintained (NAPog = -3°) (Figs 4 to 6, Table 1).

With regard to the function, tooth guidance was restored, achieving normal functional movements, with posterior disocclusion in protrusion and laterality movements with disocclusion in the balancing side, not requiring the wearing of the palatal cusp of tooth #24. Atypical swallowing, phonation, and mouth breathing were not corrected, as the patient did not seek the therapies recommended throughout orthodontic treatment.

Figure 4: Final facial and intraoral photographs.

Figure 5: Final panoramic radiograph.

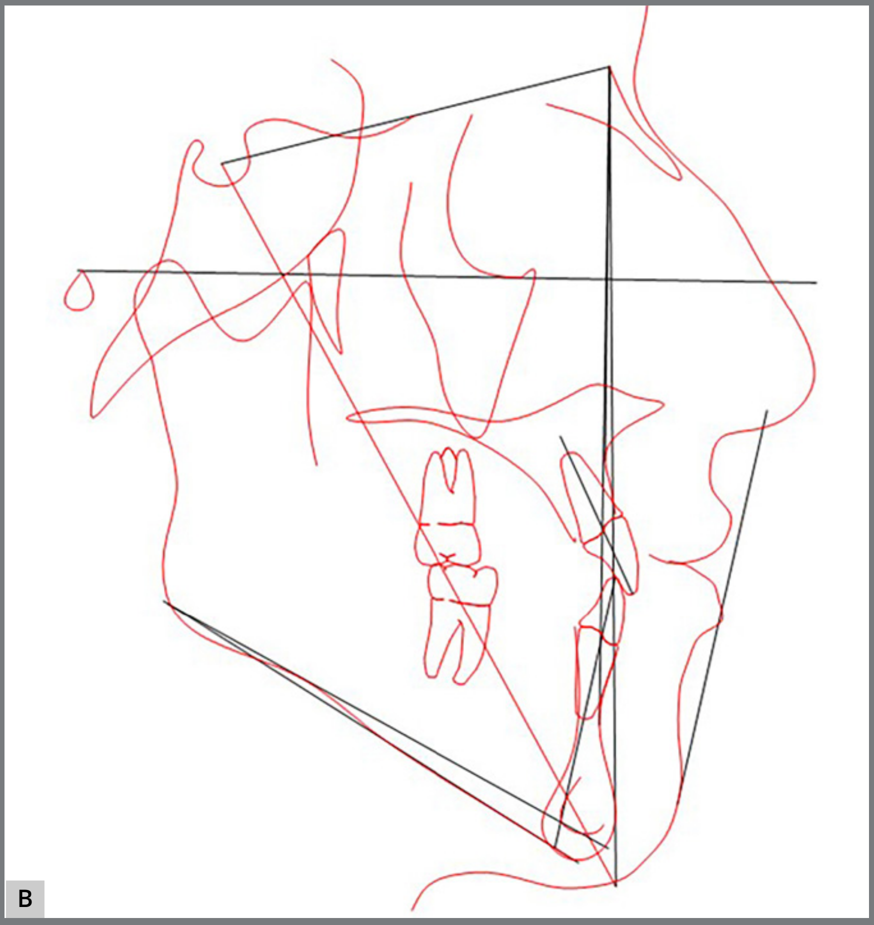

Figure 6: Final cephalometric profile radiograph (**A)** and cephalometric tracing (**B)**.

Table 1: Initial (A), final (B) and 8 years after treatment (C) cephalometric values.

	MEASURES		Normal	A	B	A/B	C
Skeletal pattern	SNA	(Steiner)	82°	75.4°	75.9°	0.5°	78.9°
	SNB	(Steiner)	80°	75.1°	75.5°	0.4°	78.2°
	ANB	(Steiner)	2°	0.2°	0.4°	0.2°	0.7°
	Wits	(Jacobson)	♀ 0 ±2mm ♂ 1 ±2mm	-5.4 mm	-2.7 mm	2.7 mm	-6.0 mm
	Angle of convexity	(Downs)	0°	-2.3°	- 3.0°	1.3°	-1.0°
	Y-Axis	(Downs)	59°	60.4°	57.4°	3.0°	64.6°
	Facial Angle	(Downs)	87°	91.4°	94.5°	3.1°	89.2°
	SN.GoGn	(Steiner)	32°	43°	43.3°	0.3°	42.3°
	FMA	(Tweed)	25°	29°	28°	1°	34°
Dental pattern	IMPA	(Tweed)	90°	73°	61°	12°	60°
	1.NA (degrees)	(Steiner)	22°	25.2°	23.9°	1.3°	19.5°
	1-NA (mm)	(Steiner)	4 mm	5.4 mm	3.4 mm	2 mm	1.5 mm
	1.NB (degrees)	(Steiner)	25°	11.6°	5.8°	5.8°	3.8°
	1-NB (mm)	(Steiner)	4mm	3.2mm	1.1mm	1.4°	0 mm
	1/1 - Interincisal angle	(Downs)	130°	142.9°	149.9°	7°	156°
	1 - APg	(Ricketts)	1mm	1.3 mm	-0.7 mm	2.0 mm	-1.5 mm
Profile	Upper Lip – Line S	(Steiner)	0mm	-2.2 mm	-4.0 mm	1.8 mm	-3.2 mm
	Lower Lip – Line S	(Steiner)	0mm	0.5 mm	-5.1 mm	4.6 mm	-3.9 mm

Figure 7: Facial and intraoral photographs 8 years after treatment

Figure 8: Panoramic radiograph 8 years after treatment.

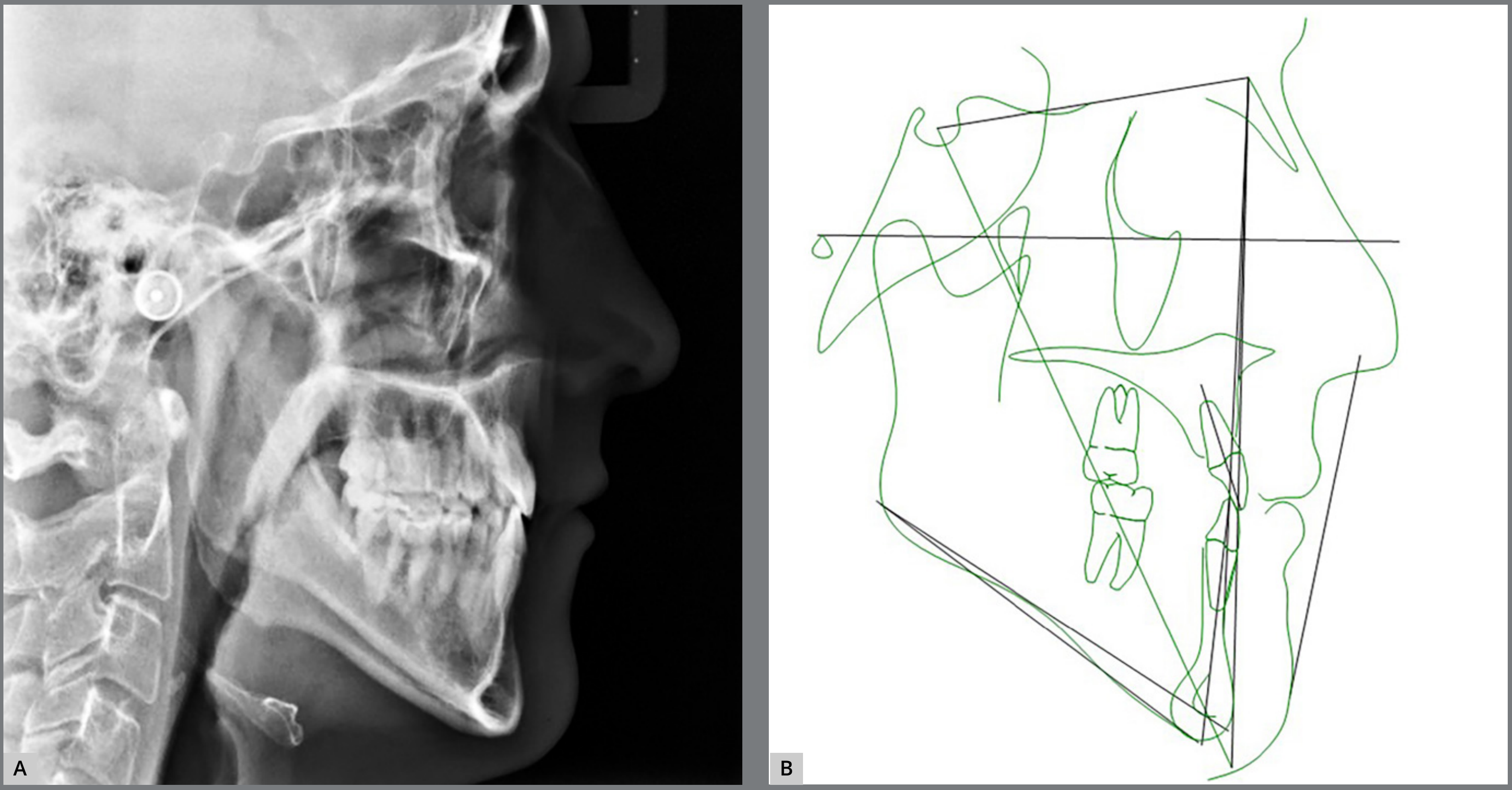

Figure 9: Cephalometric profile radiograph **(A)** and cephalometric tracing **(B)** 8 years after treatment.

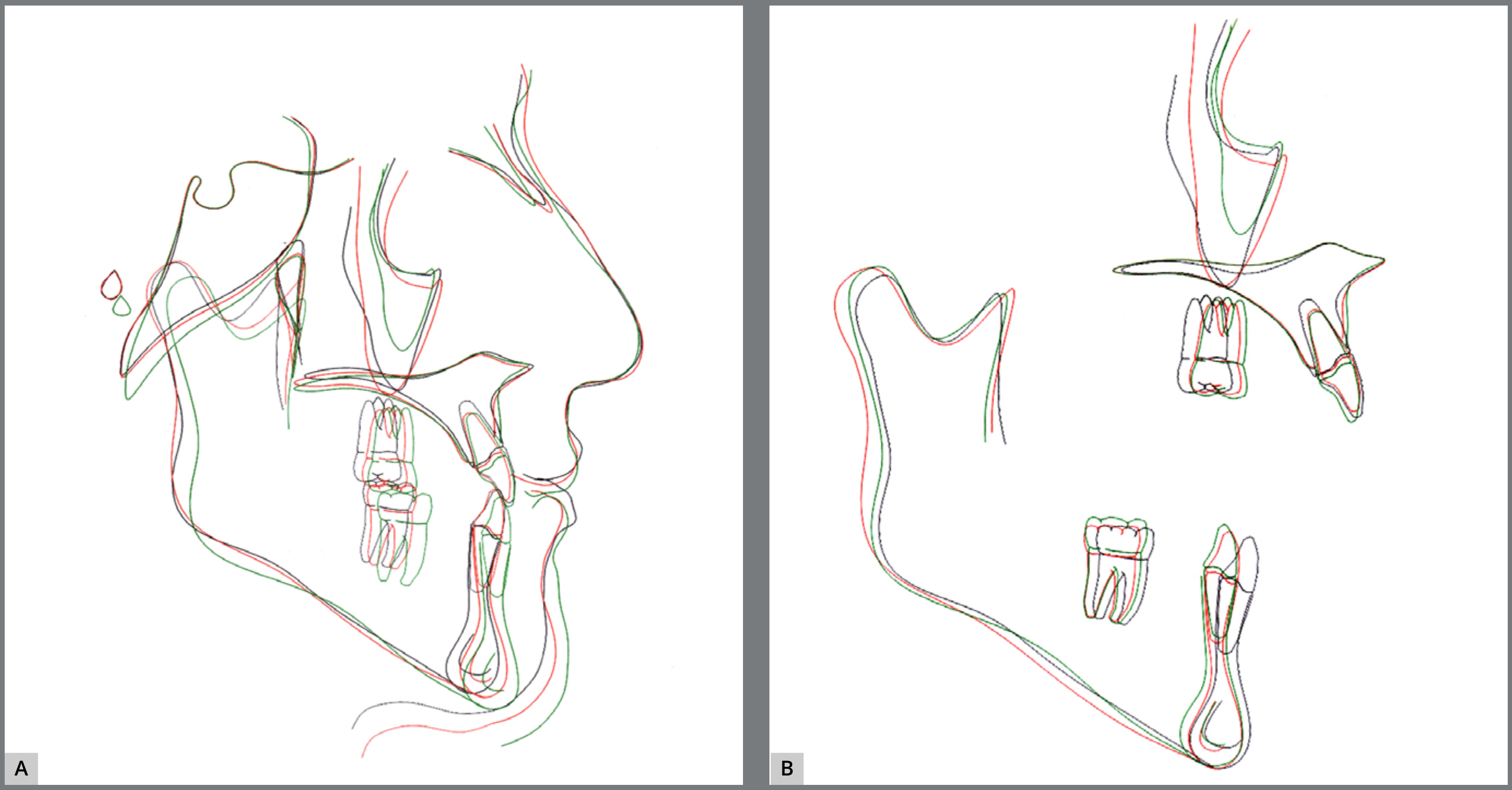

Figure 10: Initial (black), final (red) and 8 years after treatment (green) total (A) and partial (B) superimpositions of cephalometric tracings.

DISCUSSION

Patients with severe Class III skeletal deformity are often candidates for orthognathic surgery as the only choice toward normal occlusion and an esthetic profile.[14] However, the dilemma lies in the fact that most patients reject surgical therapy, persisting in orthodontic treatment. Moreover, the facial profile of Class III skeletal deformities is always the primary concern of these patients when seeking treatment. This truly is a great challenge for orthodontists, and estimating facial changes and occlusal improvements is essential when developing a treatment plan.[3] Psychological (instead of morphological) characteristics are probably a factor of significant influence for an individual when deciding about whether or not to accept surgery.[15]

Due to the relationship between age, growth, and development, early intervention methods cannot be applied to treat skeletal deformities in the permanent dentition or in adults. From this perspective, the only non-surgical alternative to manage skeletal deformities in the permanent dentition or in the adult is comprehensive treatment with fixed appliances.[8]

Nongrowing patients with moderate skeletal Class III malocclusion and acceptable facial esthetics can benefit from orthodontic camouflage,[16] especially in cases of mild to moderate skeletal discrepancies.[11] In the present case, which involved an adult patient with problems in the three planes (anteroposterior, vertical, and transverse) and indication for ortho-surgical treatment (option refused by the patient), orthodontic camouflage was chosen even with the limitations imposed by this choice (skeletal problems would not be corrected).

Despite the dissatisfaction with his smile esthetics, the patient showed a good appearance and was not bothered by his profile, which influenced his emphatic negative position regarding surgical correction. The decision for orthognathic surgery is mainly related to the self-perception of patients.[17] Although dental specialists may recommend surgical treatment, self-perceptions of the facial profile are more important in the patient's decision to choose this type of treatment.[9]

The results obtained with orthodontic camouflage were already expected. Dental compensations were performed to compensate for the existing discrepancy in the maxillary and mandibular bases, with the objective of restoring the function and providing some esthetical improvement, maintaining the initial inclination of the maxillary incisors and retroclination of the lower incisors. Troy et al.[3] analyzed Class III patients treated with camouflage and orthognathic surgery, and compared the dental and skeletal results obtained. The results of camouflage treatment did not differ from those of our study: there were no skeletal changes, the maxillary incisors were proclined, and the mandibular incisors were retroclined.

There was good control of the vertical dimension, which was already increased, and no skeletal or profile changes. Other studies showed similar results, corroborating the indication of this treatment in cases of mild to moderate skeletal Class III malocclusion.[1,3,10]

The decision for orthodontic camouflage in the present case was made by considering some important parameters. First, the skeletal Class III malocclusion was mild, with ANB = 0 and little impairment of facial esthetics, which was irrelevant for the patient. Moreover, the anteroposterior position and the initial inclination of the maxillary and mandibular incisors were satisfactory for correcting the malocclusion, and the thickness of mandibular symphysis allowed good retraction of the mandibular incisors. When associated, all these factors provided greater safety for choosing this type of treatment.[10,11]

The retroclination of mandibular incisors in the camouflage treatment can result in prominent (vestibular) roots and gingival recessions. Therefore, care must be taken to attain a proper dentoskeletal relationship, especially in cases of severe skeletal dysplasias.[3] Accordingly, the present patient was treated with great care, as he already showed significant gingival recession in tooth #33. The problem was monitored throughout treatment, and periodontal care was recommended, with rigorous dental plaque control. Canine distalization and incisor retraction were carefully performed, to maintain the normal gingival insertion levels of the incisors and prevent the increase of recession in tooth #33. Results showed that these procedures were effective, continuing throughout the retention phase (Figs 4 and 7).

It is worth highlighting the need for a long-term follow-up to control the stability of the results obtained after retracting the mandibular incisors in patients with Class III malocclusion. Considering that the mandibular incisors are retracted by 4-5 mm, the tongue has a reduced space after treatment, resulting in increased pressure on these teeth, creating spaces between them. To prevent this, ideal overjet, overbite, and intercuspation should be sought, achieving upright mandibular posterior teeth after distalization, using lower retention, and, in cases of lingual interposition at rest or during deglutition, recommending multifunctional therapy.[11] The patient did not seek the recommended services to remove preexistent deleterious habits. Nevertheless, his records for the retention phase, eight years after treatment, showed stability.

The results obtained were greatly valued by the patient, who returns annually for check-ups by his own initiative. Although not having an initially unfavorable facial esthetics, his smile bothered him. The improvement in the maxillary arch shape decreased the buccal corridor, resulting in better smile esthetics. Moreover, the elimination of mandibular crowding also contributed to these satisfactory results, with these being the chief complaints reported by the patient. The esthetic improvement resulting from malocclusion treatment enhances the oral health-related quality of life, especially for decreasing the psychological discomfort[18,19].

Significant changes in the teeth and soft tissues can be expected in young Class III patients treated with orthodontic camouflage. A wide range of skeletal dysplasias can be camouflaged by dental movement without deleterious effects to the periodontium. For that purpose, diagnosis and treatment objectives should be realistically defined to prevent undesirable sequelae.[1]

CONCLUSION

Orthodontic camouflage can be an effective treatment alternative for achieving functional occlusion, stability, and satisfactory esthetics in adult patients with mild to moderate skeletal Class III malocclusion.

AUTHORS CONTRIBUTIONS

Mônica Tirre Araújo (MTA)

Luciana Rougemont Squeff (LRS)

Conception or design of the study:

MTA.

Data acquisition, analysis or interpretation:

MTA, LRS.

Writing the article:

MTA, LRS.

Critical revision of the article:

MTA, LRS.

Final approval of the article:

MTA, LRS.

Overall responsibility:

MTA.

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

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SPECIAL ARTICLE

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Planning and orthodontic preparation for maxillary incisors reshaping

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ABSTRACT

Introduction: Having a beautiful smile is the main desire of people seeking dental treatment. To achieve this goal, many variables must be considered. These include tooth alignment, color, shape and size, besides their harmonious relationship with the lips and face. An individualized diagnosis is essential to achieve the best result. Within this context, facial analysis and the characteristics of shape, size and position of maxillary incisors play a key role.

Methods: This paper describes clinical situations in which interdisciplinary treatment was performed to achieve esthetic results in a conservative manner and ensuring greater stability. In most cases requiring reshaping of maxillary incisors for esthetic reasons, prior orthodontic movement is essential. The main focus of this paper is to discuss the many variables involved in these situations.

Results and Conclusion: The results of treatments described in this paper were obtained by means of a multidisciplinary approach, involving Orthodontics and Esthetic Dentistry, acting in harmony and recognizing their possibilities and limitations, in order to offer patients the best esthetic solution for their smile. The best treatment option is not always the easiest or fastest. The dentist, as a health professional, should consider the patients' wishes but also perform treatments with minimal intervention, and the best and most predictable esthetic result, also focusing on function and health.

Keywords: Orthodontics. Dental esthetics. Smile.

RESUMO

Introdução: Ter um sorriso bonito é o principal desejo de quem busca um tratamento odontológico. Para se alcançar esse objetivo, muitas variáveis devem ser consideradas. Entre elas, estão alinhamento, cor, forma e tamanho dos dentes, além da sua relação harmoniosa com os lábios e a face. O diagnóstico individualizado é essencial para se alcançar o melhor resultado. Nesse contexto, a análise facial e as características de forma, tamanho e posição dos incisivos superiores têm papel primordial.

Métodos: O presente artigo descreve situações clínicas em que o tratamento interdisciplinar foi realizado para alcançar resultados estéticos de modo conservador e garantindo maior estabilidade. Na maioria dos casos em que os incisivos superiores precisam ser reanatomizados por razões estéticas, a movimentação ortodôntica prévia é fundamental. O principal foco desse trabalho é a discussão das muitas variáveis envolvidas nessas situações.

Resultados e Conclusão: Os resultados dos tratamentos descritos nesse artigo foram obtidos a partir de um planejamento realizado em equipe — Ortodontia e Dentística, trabalhando em harmonia, reconhecendo as suas possibilidades e limitações, são capazes de oferecer aos pacientes a melhor solução estética para o seu sorriso. A melhor alternativa de tratamento nem sempre é a mais fácil ou a mais rápida. O cirurgião-dentista, como profissional de saúde, deve acolher os desejos dos pacientes, mas realizar tratamentos com intervenção mínima e com o melhor e mais previsível resultado estético, com foco dirigido, também, à função e saúde.

Palavras-chave: Ortodontia. Estética dentária. Sorriso.

INTRODUCTION

The esthetic composition of smile involves several harmoniously arranged factors such as tooth positioning and color, harmony of shape and size of teeth to each other and with the patient's face, relationship with the lips, facial soft tissues, bones and facial muscles.[1,2,3]

Facial analysis has become fundamental when planning orthodontic movements, orthognathic surgeries and dental rehabilitation.[3,4] Distances and angles are often used to achieve harmonious relationships between teeth and face, especially when associating facial measurements with the dimensions of maxillary incisors, which are protagonists in smile.

The importance of maxillary incisors for the smile increases the need for interdisciplinary approaches to enable the achievement of well-positioned teeth, with shape and contour compatible with the face. Thus, the orthodontic treatment should always be in line with the Restorative Dentistry treatment, aiming at a minimally invasive approach, in search for optimum outcomes.

Thus, the purpose of this paper is to present case reports with interdisciplinary approach, by means of Orthodontics and Esthetic Dentistry treatments, presenting situations in which the maxillary incisors required reshaping due to abnormalities of shape or size, disproportion between tooth size and face, discrepancy between bone bases and mesiodistal dimensions of teeth, emphasizing the criteria considered when planning the reshaping, as well as the most predictable treatment sequence. The paper also includes the description of care in the follow-up of treatment.

SITUATIONS IN WHICH THE MAXILLARY INCISORS REQUIRE RESHAPING

INCISORS WITH ABNORMALITIES OF SHAPE AND/OR SIZE

Abnormalities of shape and size are relatively common conditions in the dental clinic. Besides the third molars, the teeth most often affected by this condition are the maxillary lateral incisors[5]. Since these teeth are positioned in an important region for the smile and facial appearance, its anatomical adequacy is essential for a good esthetic outcome of any dental treatments.

When the anomaly in shape or size is related to smaller teeth, such as microdontia or peg-shaped incisors, reshaping with addition of material is indicated. However, since the proximal contacts are critical to the stability of mesiodistal position of teeth, it is very common that teeth adjacent to the smaller tooth have migrated, and thus the resulting space is not ideal for reshaping. Therefore, in most cases, orthodontic movement is necessary before restorations, in order to reestablish the ideal spaces, allowing harmonious reshaping of teeth (Fig 1).

Figure 1: Orthodontic preparation, with space opening for reshaping of lateral incisors with abnormal shape and size.

DISPROPORTION BETWEEN SIZE OF INCISORS AND FACE/SMILE

The maxillary central incisors are considered the teeth with greatest esthetic importance for the smile; thus, when planning the restorative treatment, their dimensions are frequently studied and related to the individual's face, to allow the individualization of smile. Therefore, facial references are used to determine the ideal dimensions for each face, in both horizontal and vertical dimensions.

One facial reference often used for this purpose is the interpupillary distance, a stable facial measurement that is consolidated after the age of 14 years until adulthood.[6] The value of this distance, divided by 6.6, represents the ideal mesiodistal dimension of the maxillary central incisor, i.e., its width. Thus, during dental rehabilitation, especially in the presence of interdental diastemas or excessively large or narrow incisors, this dimension aids the rehabilitation planning. Liao et al.[7] mentioned the interalar distance as another reliable parameter. After analysis of 41 papers, they concluded that the apparent width of the two central incisors in combination should be equal to 70% of the interalar distance of the individual.

Another important analysis to define the size of maxillary incisors is their exposure while smiling. This exposure should range from 3⁄4 of the clinical crown of maxillary central incisors (most common in men) to exposure of 2 mm of gingiva (mostly observed in women)[8]. If this exposure is not altered by bone discrepancies or altered dimensions of the upper lip, incisal increases or orthodontic extrusion of these teeth should be considered, aiming to achieve these parameters.

BOLTON DISCREPANCY, WITH EXCESS OF MANDIBULAR TEETH VOLUME

Bolton,[9] when evaluating 55 pairs of dental casts of patients with occlusion close to optimal, concluded that the important factors for good occlusion include the proportion between the mesiodistal dimensions of mandibular and maxillary teeth. Thus, the author established ideal values for the proportion between the sum of widths of maxillary and mandibular teeth, both for all teeth in the arch (first molar to the first molar of each arch) and for the anterior segment (canine to canine for each arch). According to their findings, the sum of widths of mandibular teeth (in the total evaluation of arches) should represent 91.3% (87.5 to 94.8%) of the sum of widths of maxillary teeth, while this proportion should be 77.2% (74.5 to 80.4%) when evaluating only anterior teeth.

If these ratio values are greatly altered, which can be considered a “tooth size discrepancy” or “Bolton discrepancy”, adjustments are necessary to achieve good occlusion. When the result of analysis of this proportion is significantly higher than the value recommended by Bolton,[9] it means that there is excess tooth volume in the mandibular arch in relation to the maxillary arch. If this discrepancy is not compensated, at completion of orthodontic treatment the situation will be as follows: canines in key occlusion, well related to each other, adequate overjet and remaining spaces between the maxillary anterior teeth (Fig 2). Thus, if the spaces are closed by retraction of incisors, an anterior crossbite will be created, while if they are closed by mesialization of posterior teeth, the canines will change from key occlusion to a Class II relationship. Neither of the two options should be considered.

Figure 2: Case of Bolton discrepancy (with excess lower tooth volume) treated by interproximal stripping of mandibular incisors and canines, and addition of resin in the maxillary incisors and canines. Even though the maxillary teeth had adequate shape and dimension, it was necessary to reshape them to avoid excessive stripping on the mandibular teeth to compensate for the tooth size discrepancy between maxillary and mandibular teeth.

To solve this situation, it is necessary to adjust the proportion between maxillary and mandibular teeth by dental reshaping. Three treatment options are available for that purpose: a) the width of mandibular anterior teeth can be reduced by interproximal stripping. Then, the spaces created by stripping are closed by retraction of mandibular incisors and consequent creation of overjet, which allows closure of upper spaces by retraction of incisors; b) open (or maintain) spaces for subsequent closure by increasing the width of maxillary anterior teeth; or c) a combination of the two options.

To choose the best option, the diagnosis and planning should be individualized. During this process, several aspects must be considered, such as the relationship between enamel thickness and the amount of wear required, harmony between size/shape of incisors and face/smile, anteroposterior positioning of the lips (facial profile) and buccolingual inclination of incisors (Fig 2). These and other important aspects for planning will be discussed in more detail in this paper.

CRITERIA TO BE CONSIDERED WHEN PLANNING THE INCISOR POSITION, BEFORE RESHAPING

PROFILE (UPPER LIP POSITION)

One of the most important aspects for facial harmony is the volume and anteroposterior positioning of voluminous and well-positioned lips, which, besides harmony, provides beauty, attractiveness, sensuality and youthfulness to the individual[10]. Thus, this aspect should be among the most important when planning any orthodontic treatment.

The positioning of lips is markedly influenced by the anteroposterior position of incisors. The more protruding the incisors, the more protruding the lips will be. The opposite is also true. The retraction of anterior teeth tends to cause lip retraction, changing the individual's facial profile.[10]

When assessing the planning of these cases, a question may arise: what is the relationship between the anteroposterior position of incisors and their mesiodistal reshaping? There is a direct relationship. When there is need to open spaces to increase the width of incisors, the teeth are protruded to occupy a more external arch and consequently more space, increasing the lip projection. Conversely, when the treatment option for Bolton discrepancy is interproximal stripping for future incisor retraction, one of the likely consequences is lip retraction. Thus, generally speaking, in a case of disproportion between the size of maxillary and mandibular teeth, if the patient has retruded lips, the treatment with space opening for posterior augmentation of teeth with restorative material is the most indicated (Figs 3 and 4). Conversely, if the lips are excessively protruded, the treatment with interproximal stripping and subsequent retraction of incisors should be chosen.

Figure 3: Bolton discrepancy, with excess lower tooth volume and retracted upper lip. Indication of protrusion and addition of restorative material in the maxillary incisors, to harmonize the proportion between maxillary and mandibular incisors and increase the upper lip volume.

Figure 4: Incisor projection (associated with interproximal stripping of mandibular anterior teeth) to dissolve the mandibular crowding, and subsequent reshaping of maxillary incisors with ceramic veneers, and lip volume harmonization.

INCLINATION OF INCISORS

If the anteroposterior position of maxillary incisors is directly related to the positioning of lips and consequently to the patient profile, the buccolingual inclination of these teeth has an important influence on the appearance of incisors during speech and smile. The characteristics of human vision lead the perception of the size of an object to occur according to the dimensions of the part of that object that reflects light horizontally.[11] As a result, when the incisors present excessive buccal tipping, their apparent height is smaller than the actual one, since part of the light on the buccal faces of these teeth is deflected upwards.

Thus, this aspect should also be evaluated when planning the reshaping of anterior teeth. When opening of maxillary anterior spaces is necessary to increase the width of incisors, there is a tendency of increased buccal tipping of their crowns. When the incisors are too upright or lingually tipped, this is favorable. However, when the initial inclination of these teeth is adequate and due to limitation of buccal bone thickness, bodily tooth protrusion cannot be performed (crown and root proportionally buccally tipped), this movement can lead to a situation in which the incisors would have an apparent length smaller than their actual length. Besides, the glare resulting from light reflection on the buccal surfaces would be displaced from the center to the incisal third,[12] assigning these teeth an unpleasant appearance,[13,14] making the smile less attractive.

In these situations, the advantages and disadvantages of each treatment option should be evaluated. When, after careful evaluation, it is concluded that the spaces must be opened for tooth augmentation, even if their resulting buccolingual inclination is not ideal, it is possible to minimize this disadvantage during restorative treatment. For that purpose, the thickness of restorative material can be increased in the cervical third of incisors in relation to the incisal. In the case of restorative treatment planning, some situations can be considered: 1) When there is no need to increase the tooth length, the thickness of restorative material on the tooth can be increased, especially in the cervical third of incisors, in relation to the incisal; and 2) When there is a need for incisal augmentation of these teeth, they can be restored with material on the entire buccal surface (veneer-type restoration), performing a slight incisal augmentation, in which this incisal third assumes a steeper inclination toward the palate, eliminating the appearance of buccal projection from the incisal edges of maxillary anterior teeth. In situations where this strategy is indicated, the material of choice can be resin, or even dental ceramics, since they allow for more efficient manipulation of the inclination of buccal surfaces of incisors (Fig 5).

Figure 5: Ceramic veneer, compensating the excessive buccal tipping resulting from the projection of maxillary incisors.

HEIGHT/WIDTH RATIO AND TOOTH SHAPE

For planning additions of material in anterior teeth, either due to the need to close mesiodistal spaces or increase the length, the dental dimensions must not only be related to the patient's face, they should always be proportional to each other, i.e., the width/height ratio of each tooth must guide the planning of addition of restorative material, avoiding excessively wide or narrow teeth or even very long or very short.

The mean width/height ratio of central incisors, the teeth most apparent in smile, is 78 to 86%, i.e., the tooth width corresponds to approximately 78 to 86% of its height.[15,16] Studies that assess and consider factors such as more recurrent dental esthetic disposition establish that this ratio should ideally be 78%,[17] leaving the central incisor slightly narrower and thus more elongated.

After defining the dimensions of central incisors, the lateral incisors and canines should be addressed. The width/height ratio of lateral incisors should be from 76 to 79%, and 77 to 81% for the canines. Also, in frontal view, the apparent width of the six anterior teeth should decrease from the midline to the posterior region, so that the canine appears to be 70% of the width of the lateral incisor and this, in turn, should appear to have a width corresponding to 70% of the central incisor.[16,17]

If it is necessary to close diastemas with restorative material (Bolton's discrepancy), the orthodontist must maintain an integrated plan with the restorative dentist, so that they can measure the teeth, especially their width, to calculate the amount of material that will be added to each individual tooth and the location where this material will be added, so that the dimensional balance of teeth is not altered.

Regardless of the option chosen by the patient and the dentist, it should be considered that the apparent width and height of teeth can be altered by many factors, from positioning of soft tissue, such as the lips, to the primary and secondary anatomy of teeth, addressing the areas of light reflection, shadow and areas of transition between teeth.

Besides the dimensional aspects of teeth, their shape and proximal aspects should be considered when planning dental reshaping. The closure of diastema in the interdental midline region, between the two maxillary central incisors, involves the need for additions on their mesial surfaces, which are usually flatter, i.e., with less convexity, complicating the shaping of composite resin without the presence of cervical excess. Conversely, the convexity of distal aspects of lateral incisors and mesial surfaces of canines facilitates the insertion of restorative material to close the interdental space in a more anatomical manner, with the use of a smaller amount of material in the cervical area, facilitating the technique and avoiding cervical excesses of restorative material (Fig 6).

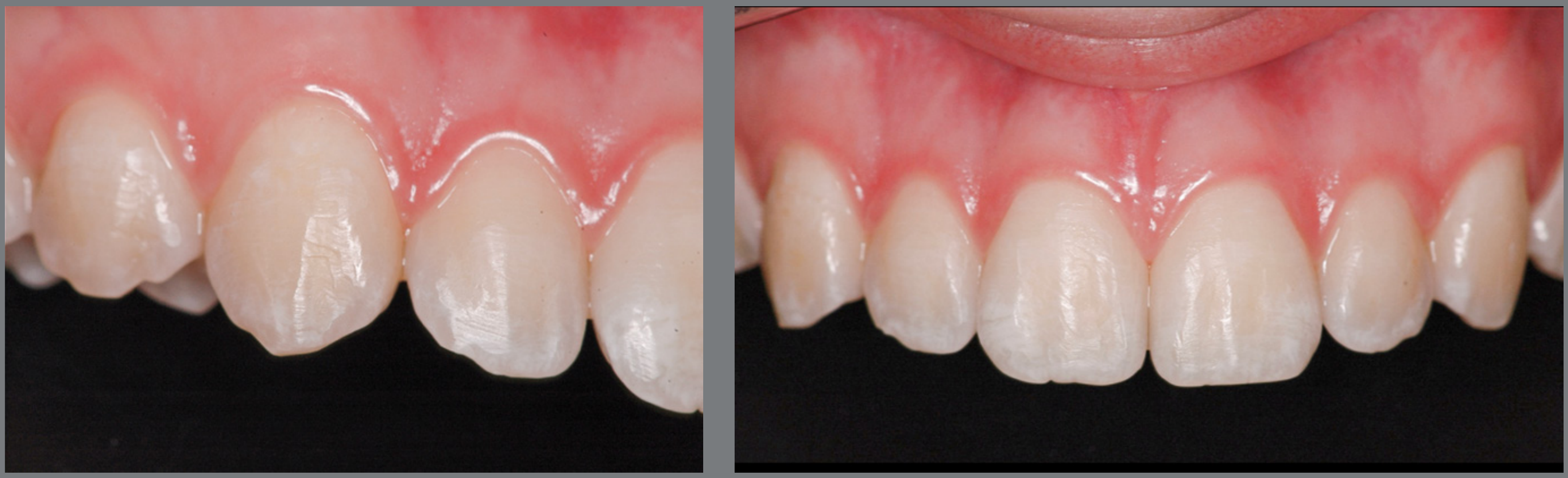

Figure 6: Detail of the shape of proximal surfaces of anterior teeth: straight mesial surfaces of central incisors, and convex distal surfaces of lateral incisors and mesial surfaces of canines.

VERTICAL POSITIONING OF INCISORS

Most aspects considered in this paper concern issues involving the planning of changes to the mesiodistal dimensions of incisors. However, as described in the previous item, the length of these teeth is as important for the esthetic result of treatment as their width — in some situations, even more.

However, when planning dental positioning prior to the increase in height, fewer variables need to be evaluated. Two of them are the most important:

» Overjet – When the maxillary incisors require elongation by the addition of restorative material, some overjet should be left, so that there is adequate space for sufficient thickness of restorative material to have the required strength. Thus, in these cases, depending on the patient's occlusion, a small retraction of mandibular incisors may be necessary, or a small projection of maxillary incisors.

» Periodontal aspects – In some situations, the height of incisors is asymmetrical, either because of tooth wear or fractures or because of asymmetry in the gingival contour (Fig 7). In these cases, it is very important to identify the reason for the lack of gingival leveling. If the cause is excess gingival tissue in one or more incisors, the most appropriate approach is periodontal surgery, so that the excess tissue is removed, and the gingival contour becomes symmetrical

Figure 7: Intrusion of tooth #11, to level the gingival margins and later reshape the incisors with ceramic veneers.

and harmonious. However, if the asymmetry occurs due to passive extrusion of a tooth whose incisal third is worn or fractured, the best alternative is harmonization of the gingival contour by orthodontic intrusion of the extruded tooth.[18] This movement will result in unleveling of the incisal edges between the intruded tooth and adjacent teeth, which will require correction by an esthetic restorative procedure (Fig 7).

In these cases, the advantage of intrusion compared to periodontal surgery is that the incisors will have balanced mesiodistal dimensions in the middle and cervical thirds, which will not occur if they are kept in position, due to the divergent shape of their crowns in incisal direction.

Therefore, a detailed periodontal examination is very important, with measurement of probing depth and evaluation of imaging exams, to reach a correct diagnosis and proper planning.

RESTORATIVE MATERIAL TO BE USED

For the addition of restorative material aiming to change the mesiodistal dimension of teeth, the positioning of interdental spaces that will be rehabilitated is directly related to the size of teeth (as aforementioned) and also to the restorative material that will be used. In the case of esthetic additions, two restorative materials can be considered: dental ceramics and composite resins.

Dental ceramics is a material widely used in restorations, such as veneers or dental crowns. The indication of this material is usually associated with the need for dental preparations that enable the creation of an insertion axis for the ceramic restoration, based on the presence of expulsive areas in the teeth. Since ceramic restorations usually involve the entire buccal surface of teeth, planning their location and shape is strongly associated with tooth dimensions and planning of the esthetic design of smile.

Composite resin is a very versatile material and can be used for partial restorations or for larger restorations — such as the entire buccal surface of teeth, for example. Besides, it is the material of choice for small additions, such as in cases of diastema closure, small shape changes and partial reconstructions, and for use in younger patients.

Despite being an esthetic restorative material, it has color instability, especially in the marginal region, when exposed to the oral environment[19] and to some substances containing dyes.[20] This change in the color of material is one of the main reasons for the replacement of restorations, especially in anterior teeth.[21] Therefore, when small additions of composite resin are used to close spaces, they should be used in less critical esthetic areas, such as the distal surface of lateral incisors, avoiding more medial regions of the smile, which are more relevant from an esthetic point of view.

In the clinical case illustrated in Figure 8, the presence of a broad central diastema is observed. When planning the closure of this diastema, some factors were considered, such as: 1) dimension of maxillary incisors (the central incisors were very large); 2) location of the diastema (central diastema); and 3) restorative material used (composite resin, chosen in agreement with the patient, due to the desire to avoid tooth stripping). Thus, due to the combination of these factors to close the diastema, it was necessary to achieve a better distribution of interproximal spaces, aiming at the esthetic balance of smile and the durability of composite resin restorations. For that purpose, the central space was shifted to the right and left sides, and positioned between the lateral incisors and canines. After tooth movement and stabilization of movement, the teeth were bleached, and spaces were closed. The central incisors were restored to re-establish the height/width ratio, esthetic composition of smile and adequate overbite.

Figure 8: Closure of midline diastema (**A-C**) by means of an interdisciplinary approach. The maxillary incisors were mesialized, to orthodontically close the diastema, displacing the spaces to the posterior region (**D-F**), avoiding the need to insert restorative material in the mesial surfaces of these teeth. To coincide the upper dental midline with the facial midline, teeth #11 and #12 were moved more than teeth #21 and #22. Then, the spaces were closed by adding composite resin on the distal surfaces of lateral incisors and mesial surfaces of canines (**G-I**). The central incisors were increased vertically to provide a better height/width ratio, a more harmonious smile arc and adequate overbite.

MORE ADEQUATE SEQUENCE OF PROCEDURES

DIAGNOSIS

Any interdisciplinary treatment requires an integrated planning. In the specific case of orthodontic treatment of a patient who will undergo some type of esthetic reshaping of maxillary incisors, besides the diagnosis and planning for correction of occlusal and facial problems, as in any other case, it is necessary to carefully evaluate all aspects discussed in the previous item, to determine the final position of teeth that will be reshaped, as well as the adjacent and antagonist teeth.

What will be the final dimensions of incisors? Which restorative material will be used? In which regions will spaces be left? What will be the dimensions of these spaces? And in vertical direction? Should any incisors be intruded or extruded? These are the questions to be answered before treatment is initiated. For that purpose, all professionals involved — orthodontist, restorative dentist and periodontist — must participate in the diagnosis and planning process.

PLANNING

To achieve greater predictability, there are tools for simulation of results that are fundamental to test the initially planned results. This phase allows an anticipated view of the results that will be achieved, which allows adjustments to the planning even before treatment onset. This procedure can be performed at various times during treatment, yet it should be done during initial planning and at the time between orthodontic finalization and accomplishment of restorative procedures. For this, there are two options: diagnostic wax-up and digital smile planning (Fig 9).

Figure 9: Waxing **(A, B, C)** and digital smile planning **(D, E)** before incisor reshaping.

TOOTH MOVEMENT

After planning the final position of teeth that will be reshaped, as well as of adjacent and antagonist teeth, the orthodontist should start orthodontic treatment to achieve the objective outlined in the planning phase. This paper does not aim to discuss the types of appliances or orthodontic mechanics; however, regardless of the strategy used by the orthodontist, after reaching the initial objective, further exams should be conducted to confirm if that configuration is the most suitable to achieve the best esthetic results as possible. At this moment, a new planning, either digital or conventional (diagnostic wax-up) should be performed. There are some cases in which the initial position of teeth does not allow for a very accurate simulation of the final configuration of smile, which becomes possible with the new tooth positions. It is very important to perform this evaluation with the orthodontic appliance in place (if brackets are used), so that small adjustments shown to be necessary can still be made (Fig 10).

Figure 10: Confirmation of the final position of teeth, with the appliance still in place, to allow for any adjustments still necessary at that moment.

BLEACHING

Almost all patients submitted to reshaping of incisors for esthetic reasons want these teeth to be lighter, in addition to larger. Thus, most of them undergo bleaching. Traditionally, the orthodontic appliance (brackets or attachments) is removed before bleaching, which leads to the need for special care with retention during this period. However, it is possible to perform bleaching with the appliance still in place.

Since the bleaching procedure takes 21 to 28 days in the average and is usually performed soon after completion of orthodontic treatment, this period is critical in relation to retention. Therefore, bleaching with orthodontic devices still in place becomes interesting, thus allowing the stability of results of orthodontic movement. Studies show that the presence of brackets does not compromise the results of bleaching, maintaining the homogeneity of bleaching along the entire buccal surface of teeth.[22,23]

Despite this advantage, bleaching techniques for patients still using orthodontic brackets are limited to bleaching techniques performed in the office or at-home techniques using pre-loaded trays. The conventional at-home technique cannot be used, due to the impossibility of making customized trays in these cases. It should be mentioned that orthodontic patients using aligners (Figs 11E and 11F) can perform at-home bleaching using their own aligners.[24]

Figures 11A to 11C show a patient shortly after orthodontic movement and still with the brackets in place, aiming to stabilize the movement, in which in-office bleaching was chosen with 37% hydrogen peroxide (Whitness Automix, FGM) used in three clinical sessions, with seven-day intervals between them. In Figure 11D, it is possible to see the harmonious and homogeneous color result obtained after in-office bleaching in a patient during orthodontic treatment.

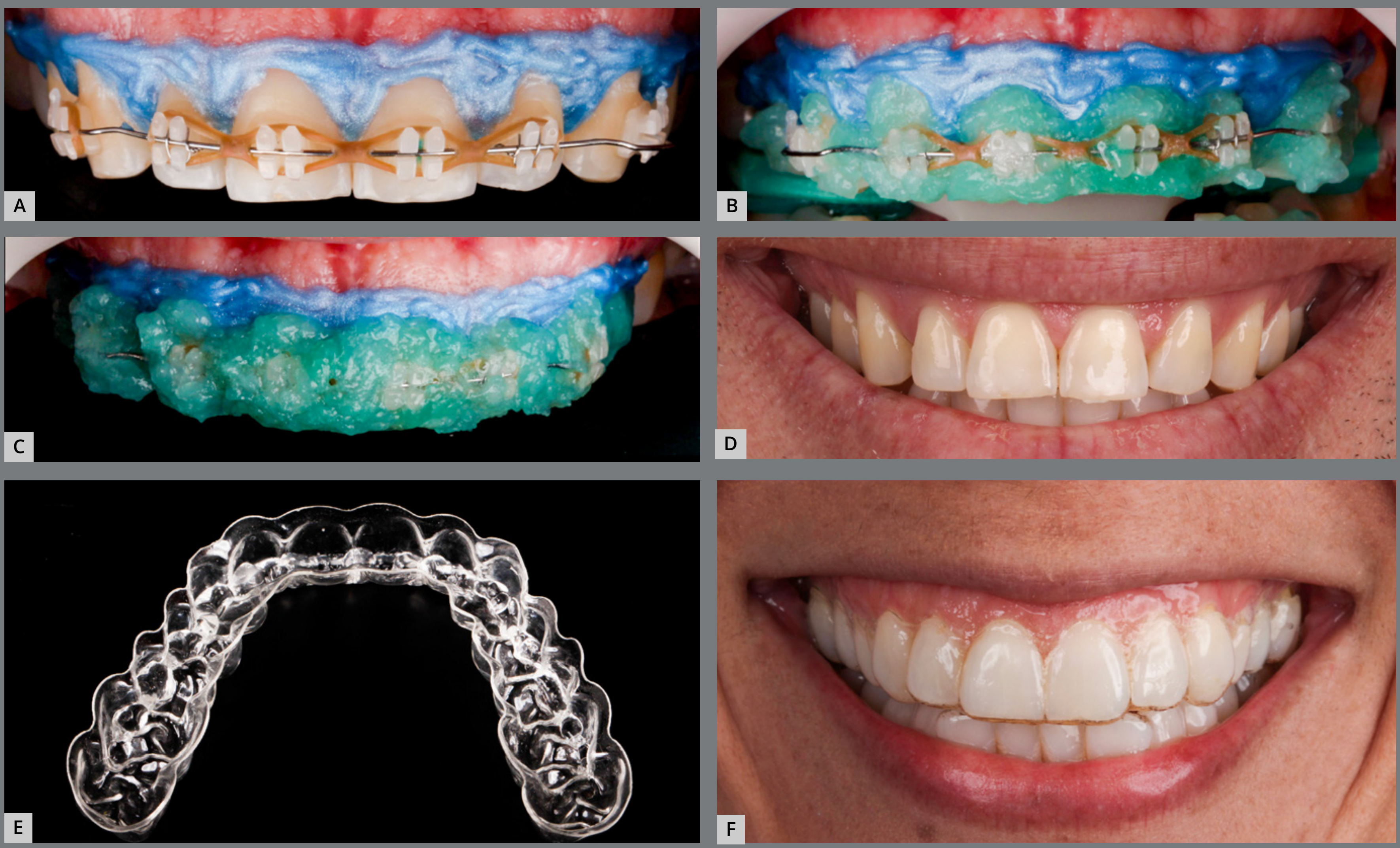

Figure 11: Bleaching performed during orthodontic treatment with brackets (**A-D)** and aligners (**E**, **F)**.

REMOVAL OF ORTHODONTIC APPLIANCE

After confirming the adequacy of position of all teeth, from an esthetic and functional point of view, the orthodontist should remove the orthodontic appliance and refer the patient to the restorative dentist. This is another moment that requires the integration between professionals involved. Since planning is done very precisely, any modification in the position of teeth can impair the result. Therefore, the time between removal of orthodontic appliance and restorative treatment should be as short as possible. To minimize risks, ideally, both procedures should be performed on the same day. For this, the professionals involved in treatment must work together and in harmony, not only with regard to the technical aspects of planning, but also with regard to their scheduling.

RESTORATIONS

Dental restorations performed on anterior teeth usually involve changes in shape, volume or dimensions of teeth, aiming at the harmonious composition of smile and the relationship between smile and face. For this, the entire project to change these teeth must be previously performed from photographs, digital plans, followed by the creation of prototypes, either by wax-ups or diagnostic models (Fig 9). This plan is shared with the patient by a test in mouth, known as a mock-up. In this test, a temporary product (bis-acrylic resin) is inserted to the patient's teeth, simulating the final treatment result, following a mold previously made from molding of the prototype. After approval by the patient of the design project for their teeth or for the composition of their smile, the actual restorations are performed.

Esthetic restorations are adhesive and should prioritize planning with minimal intervention, without unnecessary wear of teeth and respecting the masticatory function and occlusal balance. The restorative materials used for this purpose are composite resins and dental ceramics, and must be used following careful and detailed techniques — which include isolation of the operative field, judicious application of adhesive and light-curing protocols, handling of restorative material, occlusal adjustments, finishing and polishing, to ensure the longevity of esthetic restorations. Maintenance and monitoring programs for these restorations should be included in the patient's treatment.

CARE REQUIRED DURING RETENTION AND FOLLOW-UP

Any tooth that is moved tends to return to the initial position, because of the "memory" of the periodontal ligament.[25] Therefore, all patients undergoing orthodontic treatment must go through a retention period, in which appliances are placed aiming at maintaining the results achieved during treatment. The factors that contribute to the stability of tooth position after treatment include the use of retainers, the integrity of periodontium and the ratio of teeth with their antagonists (adequate intercuspation) and adjacent teeth (proximal contact points).

When the incisors are prepared for reshaping by the addition of restorative material, some of them are left without interproximal contacts until the restorations are placed, which can compromise the stability of their position, especially in mesiodistal direction. Therefore, these teeth should be kept in fixed retention until restorations are performed. This is essential to achieve the planned result. Any small relapse can compromise the space needed for the teeth to have perfectly proportional dimensions and, even worse, prevent the adaptation of ceramic restorations (whether crowns or laminates), which would cause a big waste of time and money, besides patient dissatisfaction. For esthetic reasons, these retainers can be placed on the lingual surfaces of these teeth and adjacent teeth (Fig 12). Besides, to minimize the risks, the time between removing the appliance and performing restorative procedures should be as short as possible.

After completion of the restorative stage of treatment, new retainers must be made, so that they adapt to the new dental and occlusal condition. In cases of extensive ceramic restorations, the use of acrylic occlusal plates should be considered, mainly in patients with history of bruxism, so that the restorations are preserved.

Figure 12: Fixed lingual retainer associated with removable appliance, for maintenance of incisor position during the period between removal of orthodontic appliance and accomplishment of restorations.

FINAL CONSIDERATIONS

It seems positive that we are living a moment in which esthetics is highly valued by everyone; after all, self-esteem is fundamental for people to feel good, and well-being is directly linked to health. However, it is also a time when everything has become urgent and there is a rush to solve any issue — and this is not different for dental treatments. When there is more than one treatment option, many people prefer the faster alternative; however, concerning esthetic aspects, especially involving the appearance of maxillary incisors and the smile, the quicker option may not be the most adequate or the most conservative. Many rotated or crowded incisors have been unnecessarily stripped and their remnants covered with restorative material, while orthodontic treatment alone or in combination with esthetic restorative treatment would be a more conservative treatment option.

Conservative treatments tend to provide better, more natural, longer lasting results with fewer adverse side effects. Mutilating treatments can cause irreversible damage to the esthetics of smile and oral health of patients. Above all, the dentist is a health professional and must work as such, respecting the particularities of each case, accepting the wishes of patients and always proposing to perform the most conservative treatment with the best esthetic result as possible, never deviating from the better for the patient function and health.

AUTHORS CONTRIBUTIONS

Marcelo Castellucci (MC)
Paula Mathias (PM)

Conception or design of the study:
MC.

Data acquisition, analysis or interpretation:
MC, PM.

Writing the article:
MC, PM.

Critical revision of the article:
MC.

Final approval of the article:
MC, PM.

Overall responsibility:
MC

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

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