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Why is clinical decision making not always efficient?

Flavia Artese[1]

Herbert Simon, an American social scientist, described, in 1947, in his book *'Administrative Behavior'*, the theory of decision-making. The main purpose of his work was to understand the cognitive and behavioral mechanisms that human beings use to make choices. Briefly, what Simon explains is that to make an efficient decision three steps are necessary: (*a*) to identify and list all alternatives; (*b*) to determine all consequences resulting from each alternative; and (*c*) to compare the precision and efficiency of each one of these consequences.

The process of converting all information about a problem into a decision is called judgement, which can be of an analytic or intuitive nature. The level of complexity of a problem influences the kind of judgement, which can be under certainty, when one single solution is possible; under risk, when few outcomes exist, and under uncertainty, when many outcomes are possible.[1] We tend to use intuition to make judgements on complex problems, and as odd as it may seem, judgements in orthodontics are mostly under uncertainty.[2]

Two Israeli psychologists, Amos Tversky and Daniel Kahneman, researchers on behavioral psychology, described this intuitive judgement process in the 1970's. They discovered that our brain, when facing complex decisions, that is, under uncertainty, tries to save energy. They called these mental shortcuts heuristics, a Greek word that means "I find". Basically, it is defined as problem solving using a practical method that may not be optimal, perfect or rational. Nevertheless, it is sufficient to achieve an immediate result, quickly or by approximation.

Even though we proclaim evidence-based practice, which consists of the well-known tripod of the best evidence, professional experience and patient's needs, there is still resistance in orthodontics. Apart from judgements under uncertainty, we still suffer from the lack of clear limits for what is considered a finished orthodontic treatment. It can vary from the simple alignment of teeth, with a cosmetic approach, to the ideal objectives, which include function, esthetics, tissue health and stability, with an approach focusing on health as well as beauty.

In this scenario, it is not hard to understand that some heuristic processes may happen in clinical decision-making. Heuristics of availability is the most frequent option to be remembered when solving a problem. Heuristics of representativity is a cognitive bias in which a choice is

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based on the chance of an event occurring due to the similarity to other past events already known. Both are extremely used in marketing. In this manner, our specialty has a strong tendency to choose appliances and techniques rather than an analytic process of decision-making. And this may probably explain why we have witnessed many trends of appliances and techniques, that at a certain point end up being circumscribed to their specific niches.[3]

Orthodontic practice combines science and operatory skills, which demand good professional education (including continued education) and manual dexterity, yet it has been assimilated by the world of artificial intelligence. This is not exclusive to orthodontics, since I believe most professions are feeling threatened by computer programs and robots. It may be possible that one part will be definitely performed by automation, exactly those in which decision-making is made under certainty and can thus be replaced by an operational algorithm. These facts, notwithstanding, as the level of complexity increases, our existence remains necessary. And I believe that in the future, orthodontic practice will be limited to high complexity only, demanding that professional education be even more profound to treat these cases efficiently.

Therefore, it was with certain concern that I read the excellent paper by Theodore Eliades published in the AJO-DO this last July,[4] in which he discusses the quality of the continuing education that we are receiving. In summary, the democratization of information with low evidence, wrapped in high technology, with commercial biases and with a market appeal, is the tendency of continued education of our specialty. Scientific evidence, a fundamental part of evidence-based practice, is shriveled in this scenario, and in a certain way, this conflicts with professional qualities that we will need even more in this future of high complexity only orthodontics. I am not against innovations, they are necessary and very welcome for our evolution, but they should not be confused with instant solutions or with strategies for patient enrollment. May they be part of the analytical decision-making process with the utmost concern of offering our patients not only a cosmetic treatment, but also all the complexity that a final orthodontic result demands: function, health, esthetics and stability. With no mental shortcuts.

Good reading!

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Biologix

AGORA O DENTISTA PODE AVALIAR RONCO E A APNEIA DO SONO

Fundada em 2015, a Biologix é uma empresa de tecnologia voltada para o desenvolvimento e comercialização de soluções disruptivas para a área de saúde. Nascemos com o objetivo de revolucionar o diagnóstico da apneia do sono.

A Apneia Obstrutiva do Sono (AOS), é uma doença crônica onde o paciente tem pausas na respiração enquanto dorme causadas pelo bloqueio da passagem de ar na região da garganta, na maioria das vezes acompanhadas de um ronco alto e frequente, seguido de engasgos. Em casos graves podem ocorrer até centenas de vezes por noite. É uma doença extremamente prevalente que acomete cerca de 30% da população mundial, e a grande maioria não sabe que possui.

Desenvolvemos uma plataforma para Análise da Apneia do Sono, com um exame simples, prático, eficaz e acessível para ser realizado em casa pelo paciente. A plataforma é capaz de monitorar a saturação de oxigênio no sangue (SpO2) e frequência cardíaca (FC) em tempo real, com um oxímetro compacto e confortável. Basta ele colocar o sensor no dedo e enquanto ele dorme o aparelho coleta informações sobre o nível de oxigênio no sangue e frequência cardíaca, e além dessas sobre o ronco do paciente, que são enviadas via bluetooth ao aplicativo Biologix, dispensando a necessidade de fios. Ao terminar o exame, o aplicativo gera um laudo imediatamente, com assinatura de um médico do sono e validado clinicamente.

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O exame pode ser utilizado por cirurgiões-dentistas em pacientes que possuem bruxismo, ou qualquer outro com queixas de ronco e/ou problemas com sono para diagnosticar e acompanhar a Apneia do Sono.

Em momentos adversos, é necessário a mudança de paradigmas, e nesse contexto a Biologix está comprometida em ajudar os cirurgiões-dentistas e centros de diagnóstico a melhorar sua eficiência operacional, possibilitando o diagnóstico remoto e acima de tudo, possibilitando o tratamento dos pacientes com apneia do sono.

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Matheus Melo **Pithon**[1,2]

CORONAVIRUS X ORTHODONTICS: WHAT WE NEED TO KNOW ABOUT IT!!!

The year 2020 will be marked in History by the coronavirus pandemic, which completely changed the lives of everyone on Earth. As we all know, the disease is highly contagious, transmitted by asymptomatic carriers via aerosol and droplets. The practice of social detachment, keeping a distance of 1 to 2 m between people, is widely recommended to slow or stop the spread of the virus. In orthodontic practice, this distance is difficult to maintain, given the need for orthodontic maintenance, which places orthodontists at high risk of acquiring and transmitting the infection. Much has been said about the coronavirus in general, however, information is still scarce when it is correlated with orthodontic practice. With the proposal of starting the discussion on the topic, an Arab researcher[1] carried out a literature review with the objective of informing orthodontists about the appearance, epidemiology, risks and precautions during the disease crisis. For this purpose, a literature search was performed in the PubMed, MEDLINE, Scopus and Google Scholar databases. The author highlighted the need to implement rigorous infection control measures, minimizing personal contact and the production of aerosols, since these are the keys to avoid contamination within orthodontic offices. The author also points out that although no case of COVID-19 cross-transmission in an orthodontic office has been reported, the risk exists and the disease is still emerging.

THE CORONAVIRUS PANDEMIC GENERATES ANXIETY FOR ORTHODONTIC PATIENTS

As aforementioned, the coronavirus pandemic has impacted human relations in the four corners of the world. The need to isolate oneself avoiding contagion can also cause disorders and anxieties in the patient/orthodontist relationship. With the proposal to evaluate such aspects, a group of Brazilian researchers developed a study[2] whose proposal was to evaluate the impact of the coronavirus pandemic and quarantine on orthodontic consultations and patients' anxiety and concerns regarding orthodontic treatment. To this end, a research was conducted in private dental clinics whose patients were in active orthodontic treatment. An anonymous online questionnaire was applied about their anxiety regarding the coronavirus situation, availability/acceptance to attend to an appointment, among others. The authors concluded that quarantine due to the coronavirus pandemic had an impact on orthodontic consultations and on patients' anxiety. Women were more anxious than men about the coronavirus pandemic, quarantine and impact on their orthodontic treatments. Treatment delay was the major concern of patients undergoing orthodontic treatment.

ORTHODONTISTS ANXIOUS AND CONCERNED ABOUT THE PANDEMIC

The transmission of coronavirus usually occurs through the air or through personal contact with contaminated secretions, such as droplets of saliva, sneezing, coughing, phlegm, close personal contact, such as touching or handshaking, contact with contaminated objects or surfaces, followed by contact with the mouth, nose or eyes. The mouth is our area of operation, making Dentistry among the health areas with the highest risk of contamination and virus transmission. This finding impacts all of us, and can generate anxiety and fear of returning to professional practice. On this occasion, Italian researchers developed a study[3] that aimed to investigate the anxiety of dentists regarding the return to their daily clinical activities and risk perception for them in relation to orthodontic procedures. For this, an online questionnaire was applied to Italian dentists during the last days of lockdown, with items about anxiety, fear, anguish, perceived risk for operators and concerns about orthodontic patients during the

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outbreak of COVID-19. The results showed that Italian dentists were very afraid to return to their daily activities because they considered that upon returning to work the risk of contamination for them and their families would be increased. The authors also concluded that dentists with exclusively orthodontic activity were forced to increase their working days during the week.

WHATSAPP, AN ALLY IN TIMES OF PANDEMIC

With the worsening of the pandemic, the most severe social distance, called lockdown, is now considered as a measure to prevent a greater number of contamination by the new coronavirus. Elective health treatments must be rethought and postponed. However, orthodontic treatment, which despite being elective in many cases, is still ongoing. What to do when presenting emergencies? With the proposal of clarifying to clinical orthodontists how to behave in this pandemic period, researchers from an American university published a brief summary[4] of the guidelines on orthodontic management during the coronavirus pandemic, focusing on virtual assistance to patients when they are prevented from coming to us. After searching the literature, the authors concluded that a good method for managing emergencies in this period when physical encounters are impossible is to reassure and monitor patients remotely using the WhatsApp application. The orthodontist should not let the patient use anything that may generate urgencies in the office, such as orthodontic elastics, facemasks, extraoral appliances, active lip plates or other non-removable accessories that can be activated by the patient. In emergency cases with the need for face-to-face assistance, it is essential to use specific personal protective equipment (PPE) for the occasion, following the guidelines dictated by WHO and local agencies.

LIVE, AN AUXILIARY TOOL IN THE TEACHING OF ORTHODONTICS

In times of pandemic, how do you maintain the teaching of Orthodontics? Despite the extensive workload dedicated to theoretical teaching, Orthodontics as well as other dental specialties requires laboratory practice prior to clinical care. How is the teaching of students in face of the impossibility of face-to-face meetings? In search of answers to this question, Turkish researchers developed a study[5] that aimed to evaluate the effects of a live video teaching tool on the performance of dental students in the folding of an orthodontic arch. The study involved 135 fourth-year dentistry undergraduate students. After exclusions, 116 individuals were randomly divided into two groups: Control (n = 58), in which the demonstration was performed live; and Experimental (n=58), in which the demonstration was performed on a Live. After that, the participants were evaluated regarding the execution of the orthodontic arch folding procedure. The results showed that the live video technique proved to be as effective as a conventional live demonstration for the practical teaching of orthodontics. Thus, the authors suggest that both techniques can be used as an appropriate method for training in orthodontic wire folding.

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Negligible tooth resorptions after anterior open bite treatment using skeletal anchorage with miniplates

Genivaldo dos **Santos**[1], Alberto **Consolaro**[2,3], Fernanda **Meloti**[4], Mauricio de Almeida **Cardoso**[4], Ertty **Silva**[4], An **Tien Li**[5], Monikelly do Carmo Chagas **Nascimento**[4]

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Introduction: When miniplates are used as anchoring for orthodontic mechanics for anterior open bite correction by retraction of anterior teeth and posterior teeth intrusion and retraction, orthodontically induced inflammatory external apical root resorption is clinically negligible. **Methods:** A homogeneous sample of 32 patients was used, and the roots of the teeth were compared on CT scans performed before and after orthodontic treatment. **Results:** The observed root resorption was minimal, and this can be explained by the uniform distribution of forces in several teeth, simultaneously, in the set of the dental arch and in the bone that supports the teeth. **Conclusion:** The most important thing to prevent root resorption in orthodontic practice, besides being concerned with the intensity of the applied forces, is to be careful with its distribution along the roots of each tooth, in the dental arch and in the bone that supports the teeth.

Keywords: Intrusion. Tooth resorption. Anterior open bite.

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Tooth resorption, one of the factors that limit tooth movements, should be predicted and minimized during orthodontic treatment, and its predicting factors should be identified. Among these factors are the morphology of root, apex and bone, as well as the use of intrusive mechanics and intermaxillary elastics, for example.[1,2]

Intrusion without an ideal anchorage may become one of the most complex and resorptive procedures, because of undesirable collateral movements[3-5]. Intrusion, uncontrolled pendular inclination, and translation of cortical bone are the most resorptive procedures,[6,7] particularly when torque is necessary to control them.[8,9] In fact, the forces applied during the use of intrusive mechanics, a predicting factor of tooth resorptions during orthodontic treatment, lead to inclination, and not actual intrusion. An intrusive force is perpendicular to the long axis of the tooth and forms a 90-degree angle to the bottom of the alveolus, which does not occur in clinical practice. Tooth intrusion into bone is obtained by a tipping movement, because of the inclination of anterior teeth and the root bifurcation and trifurcation angles.[5]

Force increases do not mean that the velocity of tooth movement also increases, and such forces usually lead to an increase in inflammatory external apical root resorption induced by orthodontic treatment.[10] The distribution of low intensity forces, if restricted to a single focal area, leads to the death of cementoblasts.[6] Uniform force distribution along the roots is more important than force intensity in determining the frequency and severity of external apical resorptions.[6]

The use of mini-implants as temporary anchorage devices (TAD) for intrusion has some advantages, such as their easy placement and removal in different areas, as well as their low cost. However, they may affect orthodontic movements when placed in the alveolar process between tooth roots. Moreover, they may not withstand forces greater than 150-350 g, depending on the type of bone and mini-implant diameter.[4,11] Even when placed in the infrazygomatic crest or above the external oblique ridge of the mandible, that is, on the buccal shelf, these forces are limited when compared with the ones that miniplates may withstand.

Miniplates have been developed as alternatives for larger anchorage needs. Placed in the basal bone, miniplates do not affect tooth movement, but have a greater stability and withstand much greater forces, which may be simultaneously applied on the three spatial planes — transverse, vertical and horizontal.[3,7,13] In some cases, they may be used as an alternative to orthognathic surgery, as they lead to successful bone remodeling of the dental arches.[6,7,13,14,15]

Intrusion of posterior tooth using miniplates as anchorage may be a good alternative, because tooth movement during orthodontic treatment is greater than when conventional techniques are used[10]. The use of miniplates simplifies the complexity of intrusion and prevents undesired lateral movements. At the same time, it reduces the frequency of inflammatory external apical root resorption induced by orthodontic treatments.

External apical resorptions in cases treated without miniplates may be frequent and severe. Therefore, the present study used cone-beam computed tomography (CBCT) scans of patients with an anterior open bite treated with posterior tooth intrusion to evaluate external apical resorptions in treatments with skeletal anchorage with miniplates placed in each posterior quadrant of the dental arches.

This study describes and analyzes the results of a investigative clinical study that found that the use of miniplates for orthodontic movements induces negligible external inflammatory apical resorptions[16].

METHODS

CBCT scans obtained before and after orthodontic treatment for 32 patients (23 women) with anterior open bite were selected. Minimum age was 16 years, and maximum, 55 years. Measurements before and after orthodontic treatment were made twice by a single calibrated observer at a 30-day interval. After their orthodontic treatment, the patients had a molar and canine Angle Class I relationship, and their open bite had been closed.

The roots of all teeth in the maxilla and mandible were measured on oblique sagittal and coronal slices, using the long axis of the root as a reference, from the apex to the cervical line, at the cementoenamel junction, in the buccolingual direction. The CT images obtained using an iCAT Classic scanner (Imaging Science, Hatfield, PA) were retrieved from a database for a 3D orthodontic diagnosis and miniplate placement and removal (Fig 1).

The "T" miniplates were placed in the region of the left and right infrazygomatic crest in the maxilla and in the posterior region of the external cortical bone of the mandible, at the external oblique line. The patients were treated using the same protocol:[15] standard Ricketts prescription brackets with 0.018 x 0.028-in slots (Forestadent, Pforzheim, Germany) and four miniplates placed in the left and right maxilla and the left and right mandible. Leveling, aligning and moving teeth distally were performed using a progressive increase in wire caliber: 0.012-in nickel-titanium (NiTi) (Forestadent, Pforzheim, Germany), 0.016 x 0.016-in 80-g Neo Sentalloy (Dentsply Sirona, São Paulo, Brazil), 0.016 x 0.016-in 80-g Titanol low force (Forestadent, Pforzheim, Germany), 0.016 x 0.022-in 120-g Titanol low force (Forestadent, Pforzheim, Germany), 0.016 x 0.016-in Blue Elgiloy (Rocky Mountain Orthodontics, Denver, CO) and 0.016 x 0.022-in Blue Elgiloy (Rocky Mountain Orthodontics, Denver, CO).

All posterior maxillary and mandibular teeth were moved distally using activation every three weeks. Distalization began with a 0.012-in NiTi wire, Ultra Thread Round Solid (GAC) elastomeric ligatures with a diameter of 0.030-in, tied from the miniplates to the teeth or wire, depending on the force vector necessary; force was 150-200 g for each elastomeric ligature. Subsequently, after heat-activated 0.016 x 0.016-in wires had already been inserted, the sliding-jigs were adjusted. The size of e-links (TP Orthodontics, Campinas, Brazil) was the same as the distance from the miniplate to the sliding-jig, which generated a force ranging from 100 g to 400 g for molar distalization. At this phase, according to the need of posterior intrusion and using a 150 to 200-g force, elastomeric ligatures were extended from the miniplate to the posterior part of the sliding-jig and placed in the mesial area of the first molar, or tied directly to the molar tube. Class II elastics may be used, if necessary, from the maxillary canines to the mandibular miniplates to generate a force of about 50-100 g, depending on the discrepancy of the anterior open bite.

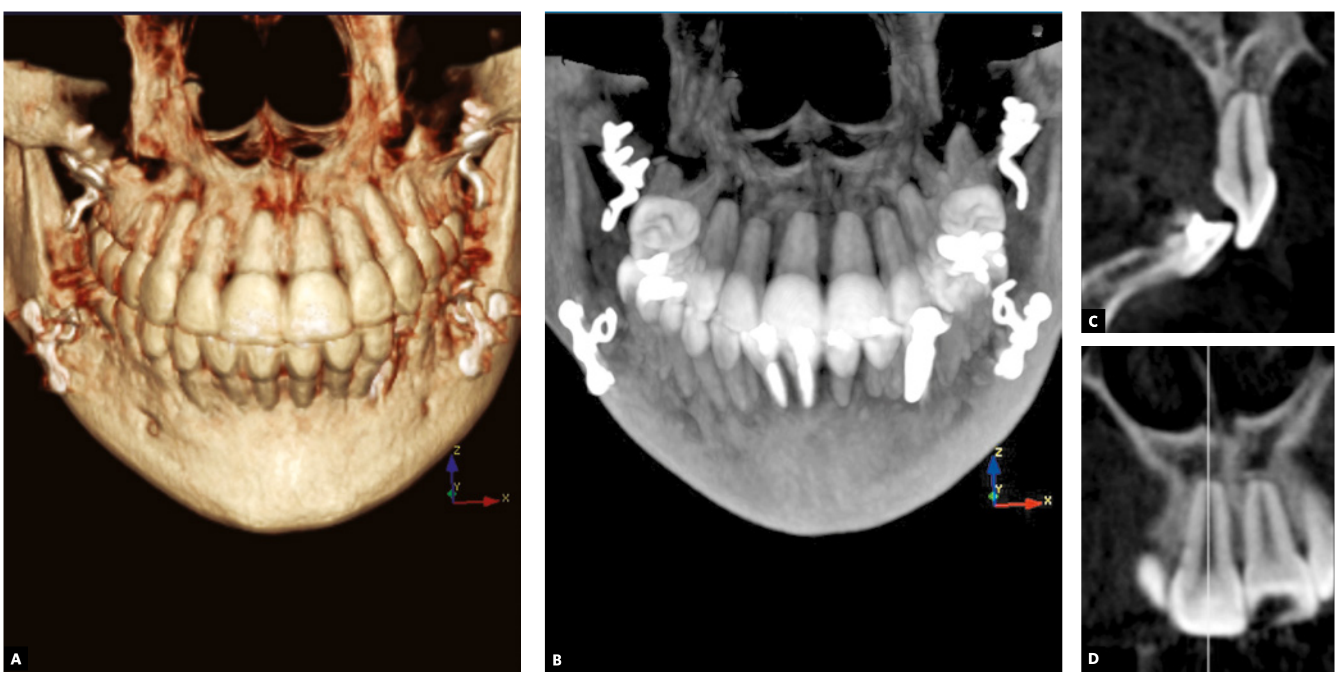

Figure 1 - Images of the patient with the largest orthodontically induced inflammatory external apical resorption in the sample studied, after the treatment of the anterior open bite with miniplates.

The anterior teeth were retracted using a segmented 0.016 x 0.016-in Blue Elgiloy wire (Rocky Mountain Orthodontics, Denver, CO) with a "C"-shaped hook at each end and placed in the disto-cervical region of the canines. A wire segment was inserted in the same slots in the anterior teeth, which already had the 0.016 x 0.016-in 80-g Titanol low force wire (Forestadent, Pforzheim, Germany). Immediately after that, elastomeric ligatures were selected, inserted in the miniplates and extended to the "C" hook of the wire segment, to retract the anterior teeth and close the space between the canines and premolars using a force of 150-300 g on each side. The cases that required space closure between the lateral incisors and canines received a modified Ricketts prescription retraction archwire fabricated using a 0.016 x 0.016-in Blue Elgiloy wire (Rocky Mountain Orthodontics, Denver, CO) and activated at its ends using forces ranging from 60 to 100 g.

The DICOM files for each patient were imported to the DTX Studio Implant 3.3.3.1 software (Nobel Biocare, Zurich, Switzerland). A more accurate analysis was conducted using image manipulation tools for brightness, contrast and filter adjustment. First, each tooth was positioned according to its long axis on oblique sagittal and coronal slices. These slices included the most central area of the tooth, so that the root apex and the crown were visualized. In the cervical area, two dots were placed at the cementoenamel junction: one on the buccal surface and the other on the lingual surface. The buccolingual line formed from one dot to the other was called cervical line. The intersection of the cervical line on the oblique coronal and sagittal slices formed a point in the cervical area called "cervical point", automatically determined by the software and visualized on the oblique coronal slice.

The values obtained were analyzed statistically using the SPSS for Windows 24.0 (IBM Corp., Armonk, NY). The Shapiro-Wilk test for normality was used to determine data distribution. As data distribution was normal, a paired *t*-test was used to compare root length before and after treatment. Measurements for the calculation of method error were made twice for the phases before and after treatment, at an interval of 30 days between measurements. Analyses were conducted using the mean value for the first and second measurements to reduce procedural errors. The formula developed by Dahlberg was used to estimate random error.

RESULTS

The difference in root length in the groups of anterior and posterior teeth before and after orthodontic treatment was statistically significant ($p < 0.01$), demonstrating a mean 0.85-mm resorption for anterior teeth and 0.69-mm for posterior teeth. Posterior root resorptions were a mean 1 mm smaller for all teeth after intrusion anchored to miniplates. All posterior teeth had resorptions of less than 1 mm. In the group of anterior teeth, 50% had resorptions smaller than 1 mm, and the rest, slightly greater than 1 mm, at a maximum of 1.17 mm.

The analysis of intraobserver agreement in the evaluation of anterior teeth revealed a statistically significant difference for teeth #32 ($p = 0.018$, 0.19 mm) and #43 ($p = 0.018$, 0.19 mm). In the posterior teeth, a significant difference was found for premolars #34 ($p = 0.002$ – 0.29 mm) and #35 ($p = 0.009$, 0.22 mm), as well as for molars #17 ($p = 0.037$, 0.14 mm) and #26 ($p = 0.042$ – 0.32 mm). There was a systematic error, that is, *p*-value was < 0.05, in the measurement of these teeth. However, the measurement error was up to 0.32 mm only, which is not clinically significant.

DISCUSSION

Although intrusion was performed in the posterior region, the anterior teeth had a greater level of inflammatory external apical root resorption induced by orthodontic treatment. This may be explained by the need to retract the anterior teeth using sliding mechanics and torque control, which was achieved using the auxiliary archwire segment and forces ranging from 150 g to 200 g.

Some cases also required the use of a modified Ricketts prescription retraction archwire (60-100 g) and Class II elastomeric ligatures (50-100 g). Intrusion, pendular inflection and translation of the cortical bone are the most resorptive movements.[6,7] The factors that contributed to inflammatory external apical root resorption induced by orthodontic treatments in the anterior teeth were:

a) The forces were applied to the crowns, far from the tooth center of resistance, an inherent factor of all orthodontic techniques.

b) The natural inclination of teeth.[9,14,17]

c) The anatomic root characteristics, which predict inflammatory external apical root resorption induced by orthodontic treatment in the groups of incisors.

d) The concentration of forces in the apical third, because of the absence of bone deflection.

e) The greater movement of incisors during orthodontic treatment.[8,9]

Intrusion performed according to conventional Orthodontics has results of little clinical significance when compared with other types of movement. Its limitations produce undesired movements, which contribute to an increase in treatment time and more severe resorptions.[7,9] Therefore, it is classified as the most complex mechanics, and its resorptive potential is accentuated with the increase of force application time and the inclusion of torque to control it.[18]

In this study, posterior teeth intrusion used forces of 150-200 g applied and distributed to the groups of posterior teeth and reactivated every 21 days. In proportion, the ideal force for the intrusion of posterior teeth corresponds to the force inside a blood capillary vessel, which includes light and heavy forces of 25 g and 225 g. Treatment time, intermittent or continuous force application and force intensity affect the level of inflammatory external apical root resorption induced by orthodontic treatment. *In vitro* studies showed a low level of this type of inflammatory resorption when the treatment includes intrusion, mini-implants as TAD and forces of 50-200 g.[5,10] Intrusion results were significant, and inflammatory external apical root resorption induced by orthodontic treatments was not always found.

Quantitative studies evaluated the level of root resorption using mini-implants as TAD, and examined all maxillary and mandibular roots before and after the intrusive treatment with forces ranging from 200 g to 300 g and reactivated every 15 days. They found that the presence of inflammatory external apical root resorption induced by orthodontic treatment was statistically significant, but, because resorptions measured 0.34 mm to 0.74 mm only, they were not clinically significant.

A study with dogs[3] to investigate posterior tooth intrusion using miniplates and forces of 100-150 g found inflammatory external apical root resorption induced by orthodontic treatments measuring 0.1 mm into cementum four months after the beginning of the treatment, and the results of intrusion were significant. In a study with patients, mean differences of 0.5 mm between root length before and after treatment were found, but these results were not clinically significant.[22]

Although mini-implants and miniplates produce similar external inflammatory resorption and intrusion, mini-implants as TAD have limitations. They affect tooth movements when placed in the alveolar bone, between tooth roots and, mainly, they do not withstand very high forces, of 150-350 g,[11] not even when placed in the infrazygomatic crest or above the external oblique line of the mandible, on the buccal shelf.[12,14]

Miniplates are recommended for more complex cases that require more extensive movement. As they withstand greater forces, simultaneous tooth movements in the transverse, vertical and horizontal planes can be attempted, and clinical results are better than those obtained when using mini-implants as TAD.[3,6,7]

Miniplates also affect all the extent of the maxilla and mandible, and the side effects of bone remodeling produced by miniplates contribute to the correction of anterior open bites, reducing treatment time[15]. Lateral radiographs of treatments using skeletal anchorage with miniplates for intrusion revealed a significant 1.76-mm intrusion of maxillary molars and non-significant inclination, with a reduction of the anterior facial height, counterclockwise rotation of the mandible and changes in the occlusal plane.[23] In extremely complex cases, the indication of miniplates may be a valid non-surgical treatment alternative. The use of miniplates results in bone remodeling in cases for which not even orthognathic surgery would be an ideal solution.[5,14]

Few studies have investigated the magnitude of inflammatory external apical root resorption induced by orthodontic treatments associated with posterior tooth intrusion using skeletal anchorage with miniplates. This study is, to our knowledge, the first to clinically evaluate all posterior teeth in treated individuals. The amount of root resorption in all teeth was analyzed using 0.4-mm voxel CBCT scans, including images previously obtained. These images were used to make a diagnosis and a 3D orthodontic treatment plan. Although this voxel size is not classified as high resolution, studies about root resorption found no statistic differences when smaller voxels were used, particularly when resorption is in the apical third of the root.[25,26]

Further CT studies should measure posterior tooth intrusion using skeletal anchorage with miniplates and after bone remodeling, to evaluate the effects of this technique for the correction of anterior open bite.

FINAL CONSIDERATIONS

External orthodontically-induced inflammatory apical root resorptions were clinically negligible after orthodontic treatment to correct anterior open bite by retraction of anterior teeth and intrusion and retraction of posterior teeth anchored in miniplates.

The distribution of uniform forces to several teeth simultaneously may explain why the apical resorptions associated with orthodontic movement were negligible when using miniplates for skeletal anchorage. This technique reduces the chances of vascular compression in the periodontal ligaments, which would lead to the death of cementoblasts, exposure of the mineralized portion of the root and attraction of clasts, and therefore, with consequent root resorptions. These findings suggest that the most important step to prevent root resorptions in orthodontic practice is to pay attention not only to the intensity of forces applied, but also, and more importantly, to their distribution to the roots of each tooth, the dental arch and the bone that supports the teeth.

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Incisor root length in individuals with and without anterior open bite: a comparative CBCT study

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Objective: This study aimed to compare the root length of maxillary and mandibular incisors between individuals with open bite *versus* matched individuals with adequate overbite.

Methods: This comparative, matched and retrospective study included 48 cone beam computed tomographies (CBCTs) obtained at a university radiological center. Scans belonged to 24 individuals with open bite (overbite ≤ 0 mm) and 24 individuals with adequate overbite (controls). Both groups were matched by age, sex, malocclusion classification and skeletal characteristics (ANB and FMA angles). Root length of each maxillary and mandibular incisor was measured in millimeters (mm) in a sagittal section from a perpendicular line to the enamel cement junction until the root apex (384 length measurements were made). The means of root length in both groups were compared using *t*-tests. In addition, correlations between variables were evaluated with the Pearson correlation coefficient ($\alpha = 0.05$).

Results: In both groups, the root length of the upper central incisors was approximately 12 mm and the root length of the maxillary lateral incisors was approximately 13 mm ($p > 0.05$). Likewise, the root length of lower central incisors in both groups measured approximately 12 mm ($p > 0.05$). However, the mandibular lateral incisor roots of open bite patients were significantly longer than in the normal overbite patients (approximately 1 mm, $p = 0.012$ right side, $p = 0.001$ left side).

Conclusions: Root length of maxillary incisors and central mandibular incisor is similar in individuals with or without open bite, but the mandibular lateral incisor roots in open bite patients were significantly longer than in the normal overbite patients.

Keywords: Open bite. Incisor. Root length. Cone-beam computed tomography.

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Cephalometric and occlusal changes of Class III malocclusion treated with or without extractions

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Objective: The aim of this retrospective study was to evaluate the cephalometric and occlusal changes of orthodontically treated Class III malocclusion patients.

Methods: The experimental groups comprised 37 Class III patients treated: G1) without (n=19) and G2) with extractions (n=18) . The control group (G3), matched by age and sex with the experimental groups, consisted of 18 subjects with untreated Class III malocclusion. Cephalometric (radiographs) and occlusal (study models) changes were assessed between the beginning (T_1) and the end (T_2) of treatment. Intergroup comparisons were performed with one-way ANOVA followed by Kruskal-Wallis tests ($p < 0.05$). Occlusal changes were evaluated by the peer assessment rating (PAR) index (ANOVA and Kruskal-Wallis tests), and the treatment outcomes were evaluated by the Objective Grading System (OGS) (*t*-tests).

Results: The experimental groups showed a restrictive effect on mandibular anterior displacement and a discrete improvement in the maxillomandibular relationship. Extraction treatment resulted in a greater retrusive movement of the incisors and significant improvements in the overjet and molar relationship in both groups. The PAR indexes were significantly reduced with treatment, and the OGS scores were 25.6 (G1) and 28.6 (G2), with no significant intergroup difference.

Conclusions: Orthodontic treatment of Class III malocclusion patients with fixed appliances improved the sagittal relationships, with greater incisor retrusion in the extraction group. Both the extraction and non-extraction treatments significantly decreased the initial malocclusion severity, with adequate and similar occlusal outcomes of treatment.

Keywords: Cephalometric changes. Occlusal changes. Class III malocclusion. Orthodontic treatment.

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INTRODUCTION

Class III malocclusion is a controversial subject among researchers concerning diagnosis, prognosis, and treatment, especially because of the unpredictable and potentially unfavorable nature of mandibular growth. The most common treatment alternatives for correction of this malocclusion include orthopedic devices in the mixed or early permanent dentition or in adolescent patients.[1,2] In the permanent dentition, the treatment approaches may consist of fixed appliances associated with Class III elastics[3-5] for dentoalveolar compensation, with or without extractions.[6-8] Adult patients who present severe skeletal Class III deformity are usually potential candidates for orthognathic surgery to correct the skeletal anomaly.[9]

Studies described the dentofacial changes induced by orthopedic Class III treatment.[1,2] However, except case reports, only a few have actually studied fixed appliances treatment changes in Class III malocclusion patients. The main effects of various approaches used in Class III malocclusion treatment are: maxillomandibular relationship and facial esthetics improvements, increase in lower anterior face height, protrusion of maxillary incisors, retroclination of mandibular incisors, correction of overbite, overjet and molar relationship.[3-6,8,10,11] The treatment can be performed without extractions[10] or with different extraction protocols.[11-14]

Few studies have compared the treatment effects with a control group to discriminate these changes from the usual craniofacial growth changes.[4,7,12] Battagel and Orton[3] used three groups: non-extraction treatment, mandibular premolar extraction treatment, and an untreated control group. In Class III treatment with fixed appliances, only Faerovig and Zachrisson[13] and Janson et al[8] assessed the occlusal changes on dental casts.

Therefore, the objective of this study was to compare the cephalometric and occlusal changes of Class III malocclusion patients treated with or without 4-premolar extractions and untreated Class III malocclusion subjects.

MATERIAL AND METHODS

Sample

This research was submitted and approved by the Ethics in Research Committee of Bauru Dental School, University of São Paulo (CAAE 48128915.6.0000.5417). Data was retrospectively and randomly obtained from files of two different study centres at the pre- (T_1) and posttreatment (T_2) (or observational) stages. Initially, all patients presented Class III molar relationship at least on one side. The sample size was calculated to be 17 patients (α=5%, β=20%, minimum difference = 2 mm and SD = 2 mm in Wits appraisal change).[4]

The experimental groups comprised patients treated at Bauru Dental School, University of São Paulo (Brazil). Group G1 consisted of 19 patients treated without extraction and group G2, of 18 patients treated with 4-premolar extractions protocol. Orthodontic treatment was performed with fixed Edgewise appliances, with 0.022 x 0.028-in conventional brackets and the usual archwire sequence (initial 0.014-in NiTi, followed by 0.016, 0.018, 0.020 and 0.019 x 0.025-in stainless steel archwires). According to the type of malocclusion, it was associated with rapid maxillary expansion using Hyrax appliance (due to transverse discrepancy) and Class III elastics, to correct the anteroposterior relationships. Crowding was corrected with expansion of the leveling archwires and stripping. In extraction treatment, the initial canine retraction was performed on a round continuous 0.014-in NiTi archwire and the anterior teeth retraction, with rectangular stainless steel archwires, both with elastomeric chains. The control group (G3) consisted of 18 subjects with untreated Class III malocclusion from the Burlington Growth Centre, located at Faculty of Dentistry, University of Toronto, Canada (Table 1).

Cephalometric evaluation

The lateral cephalometric radiographs were hand traced by one examiner. The image magnification factors of the radiographs ranged from 6% to 9.8%. The cephalometric tracings were then digitized (Lexmark, model MX810 Series, Lexington, Kentucky, USA) and analyzed with Dolphin Imaging v. 11.7 Premium software (Patterson Dental Supply, Inc., Chatsworth, California, USA). Twenty seven variables were used: 11 angular and 16 linear (Table 2).

Occlusal evaluation

The occlusal changes were measured by the same examiner on dental casts using the Peer Assessment

Table 1 - Intergroup comparability.

	G1		G2		G3		p
	Mean	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**	
T_1 (age in years)	14.3	(2.5)	14.8	(2.3)	14.0	(1.2)	0.571 ∫
T_2 (age in years)	17.6	(2.5)	17.7	(2.4)	17.8	(2.3)	0.972 ∫
Treatment or observational time (years)	3.3	(1.4)	3.0	(0.8)	3.8	(2.4)	0.974 €
SEX							
Male	7 (12.7%)		7 (12.7%)		10 (18.2%)		0.458 Ω
Female	12 (21.8%)		11 (20.0%)		8 (14.6%)		

∫ = ANOVA test. € = Kruskal-Wallis test. Ω = Chi-square test.

Table 2 - Cephalometric variables.

VARIABLES	
MAXILLARY COMPONENT	
SNA (degrees)	SN to NA angle
A-NPerp (mm)	Linear distance from A-point to nasion-perpendicular
Co-A (mm)	Condylion to A-point distance (effective maxillary length)
MANDIBULAR COMPONENT	
SNB (degrees)	SN to NB angle
P-NPerp (mm)	Linear distance from pogonion to nasion-perpendicular
Co-Gn (mm)	Condylion to gnathion distance (effective mandibular length)
MAXILLOMANDIBULAR RELATIONSHIP	
ANB (degrees)	NA to NB angle
Wits (mm)	Distance between perpendicular projections of points A and B on the functional occlusal plane
NAP (degrees)	Angle between points N, A, and P
GROWTH PATTERN	
SN.GoGn (degrees)	SN to GoGn angle
ANS-Me (mm)	Distance from ANS to menton (lower anterior face height)
SN.OccPlane (degrees)	SN to occlusal plane angle
MAXILLARY DENTOALVEOLAR COMPONENT	
1.NA (degrees)	Maxillary incisor long axis to NA angle
1-NA (mm)	Distance between most anterior point of crown of maxillary incisor and NA line
1-PP (mm)	Perpendicular distance between incisal edge of maxillary incisor and palatal plane
1.PP (degrees)	Maxillary incisor long axis to palatal plane angle
1-AP (mm)	Distance between most anterior point of crown of maxillary incisor and A-P line
MANDIBULAR DENTOALVEOLAR COMPONENT	
1.NB (degrees)	Mandibular incisor long axis to NB angle
1-NB (mm)	Distance between most anterior point of crown of mandibular incisor and NB line
1-PM (mm)	Perpendicular distance between incisal edge of mandibular incisor and mandibular plane
1.PM (degrees)	Mandibular incisor long axis to mandibular plane (Go-Me) angle
DENTAL RELATIONSHIPS	
Overbite (mm)	Distance between the incisal edges of maxillary and mandibular incisors, perpendicular to the occlusal plane
Overjet (mm)	Distance between the incisal edges of maxillary and mandibular incisors, parallel to the occlusal plane
Molar Relation (mm)	Distance between mesial points of maxillary and mandibular molars, parallel to Frankfort plane
SOFT TISSUE	
UL-S Line (mm)	Perpendicular distance between line S and UL (most anterior point of upper lip)
LL-S Line (mm)	Perpendicular distance between line S and LL (most anterior point of lower lip)
G'.Sn.P' (degrees)	G'Sn to SnP' angle (Facial Convexity)

Rating (PAR) index[15] with a 0.01-mm precision digital caliper (Mitutoyo Corp, Kanogawa, Japan). Higher scores indicate higher levels of irregularity. This evaluation quantified the initial malocclusion severity (PAR_1), the occlusal treatment results (PAR_2), the PAR treatment or observation changes (PAR_{2-1}) and the percentage of PAR change (%PAR), using the following formula[16]:

$$\% PAR = (PAR_{2-1} / PAR_1) \times 100$$

The quality of the occlusal and radiographic results of the orthodontic treatments was evaluated with the Objective Grading System (OGS), recommended by The American Board of Orthodontics.[17] For each parameter that deviates from ideal, points are subtracted according to the problem severity. An ideal occlusion and alignment achieve a score of 0 points.

Error study

After 28 days, the same examiner remeasured 12 radiographs and 12 dental casts randomly selected, to calculate the random errors with Dahlberg's formula[18] and the systematic errors with dependent *t*-tests ($p < 0.05$).[19]

Statistical analysis

Kolmogorov-Smirnov tests were performed to check for normal distribution. Intergroup age comparability was evaluated with one-way ANOVA (normal distribution) and Kruskal-Wallis (non-normal distribution) tests. Chi-square test was used to evaluate intergroup sex distribution.

Analysis of variance, followed by Tukey tests, was performed to compare the cephalometric and occlusal statuses at T_1 and the treatment or observation changes (T_2-T_1) of the groups. Variables without normal distribution were compared with Kruskal-Wallis, followed by Duncan tests. Intergroup comparison of the OGS was performed with *t*-test. All statistical analyses were performed with Statistica software (v. 7.0; StatSoft Inc., Tulsa, Okla, USA) at a significance level of $p < 0.05$.

RESULTS

There were no significant systematic errors and the cephalometric random errors ranged from 0.27mm (overjet) to 2.25mm (Pg-NPerp). The occlusal random errors ranged from 0.91 (PAR) to 1.40 (OGS). The groups were comparable regarding initial and final age, treatment or observational time, and sex distribution (Table 1).

Group 1 showed greater mandibular protrusion and length, which contributed to the more accentuated skeletal Class III relationship and a significantly greater profile concavity than the other groups (Table 3). The growth pattern of this group was also slightly more horizontal. The treatment groups showed greater labial tipping and significantly greater protrusion of the maxillary incisor and Class III molar relationship severity than the control group. The soft tissue characteristics were similar between the groups.

The orthodontic treatment improved the maxillomandibular relationship due mainly to the tendency of a more restrictive effect on mandibular anterior displacement, when compared to the control group (Table 4).Group 1 showed significantly greater advancement of the maxilla than the other groups. Groups G1 and G3 showed slight increase in maxillary incisor protrusion, whereas group G2 showed retrusion. In general, the mandibular incisors had greater retrusion and vertical control in G2 than in the other groups. The treated groups showed significantly greater improvement in molar relationship and in the overjet. The soft tissue changes were similar in the groups.

Initially, group G2 presented significantly greater occlusal Class III malocclusion severity (Table 5). Malocclusion severity of groups G1 and G2 clearly was significantly reduced with treatment, whereas in the untreated patients it increased. Although the malocclusion reduction amount was significantly greater in G2, the percentage of PAR improvement was similar in the treated groups, as well as the final quality of orthodontic treatment.

Table 3 - Intergroup comparison before treatment (T1, ANOVA, followed by Tukey tests).

	G1		G2		G3		P
	Mean	(SD)	Mean	(SD)	Mean	(SD)	
			MAXILLARY COMPONENT				
SNA	83.9	4.2	81.6	4.7	83.7	3.0	0.169
A-NPerp	-0.7	3.7	-0.3	4.0	-1.6	3.2	0.520
Co-A	83.0	3.9	82.1	3.7	81.4	2.9	0.378
			MANDIBULAR COMPONENT				
SNB	85.5^{A}	4.0	81.8^{B}	4.5	82.9^{AB}	2.5	0.012*
P-NPerp	4.0^{A}	5.3	1.1^{AB}	6.8	-2.6^{B}	6.7	0.009*
Co-Gn	116.9^{A}	6.8	112.7^{AB}	5.6	109.8^{B}	4.4	0.002*
			MAXILLOMANDIBULAR RELATIONSHIP				
ANB	-1.6^{A}	1.8	-0.2^{AB}	1.9	0.8^{B}	1.8	0.001*
Wits	-5.9	2.4	-4.6	2.6	-4.2	2.3	0.086
NAP	-6.0^{A}	4.2	-1.8^{B}	4.6	-0.6^{B}	4.6	0.001*
			GROWTH PATTERN				
SN.GoGn	28.6^{A}	4.3	33.5^{B}	4.5	30.6^{AB}	4.4	0.005*
ANS-Me	65.2^{A}	5.0	64.5^{AB}	3.9	61.6^{B}	3.6	0.033*
SN.OccPlane	11.1	5.0	14.3	5.3	14.5	3.4	0.055
			MAXILLARY DENTOALVEOLAR COMPONENT				
1.NA	31.7^{A}	6.2	30.2^{AB}	5.5	26.0^{B}	4.8	0.008*
1-NA	6.4^{A}	2.1	6.8^{A}	2.5	4.7^{B}	1.4	0.007*
1-PP	26.8	2.1	26.9	2.8	25.7	1.9	0.209
1.PP	120.0	5.2	119.1	6.0	117.2	5.5	0.294
1-AP	4.3	2.3	6.1	2.5	4.4	2.3	0.051
			MANDIBULAR DENTOALVEOLAR COMPONENT				
1.NB	23.7	6.3	26.4	6.4	23.1	7.9	0.308
1-NB	3.1	2.1	4.9	2.7	3.7	2.4	0.088
1-MP	37.3	3.1	37.4	2.1	35.5	2.9	0.071
1.MP	86.9	7.4	88.6	6.6	86.9	9.4	0.760
			DENTAL RELATIONSHIPS				
Overbite	0.5	1.2	0.4	1.1	0.8	0.7	0.453
Overjet	1.3	1.7	1.7	1.7	2.1	0.9	0.279
Molar Relation	-4.6^{A}	1.4	-4.5^{A}	1.7	-3.3^{B}	1.4	0.022*
			SOFT TISSUE				
UL-S Line	-2.2	2.2	-0.7	2.5	-0.5	2.4	0.073
LL-S Line	-0.2	2.7	2.0	2.6	0.6	3.5	0.081
G'.Sn.P'	172.5	5.3	168.4	5.1	170.0	4.7	0.079

* Statistically significant at $p<0.05$. Different superscript letters represent statistically significant differences.

Table 4 - Intergroup comparison of treatment and growth changes (T2-T1, ANOVA, followed by Tukey tests).

	G1		G2		G3		P
	Mean	(SD)	Mean	(SD)	Mean	(SD)	
MAXILLARY COMPONENT							
SNA	0.3	2.0	0.4	1.4	0.4	2.5	0.990
A-NPerp	0.6[A]	2.2	-1.5[B]	2.7	0.3[AB]	2.3	0.023*
Co-A	0.5[A]	2.4	0.3[A]	1.8	2.7[B]	3.3	0.011
MANDIBULAR COMPONENT							
SNB	-0.1	1.6	0.5	1.6	1.4	2.4	0.077
P-NPerp	1.4[AB]	4.1	-1.9[A]	5.0	2.3[B]	5.1	0.027*
Co-Gn	2.5	3.8	2.2	2.9	6.8	6.8	0.154 €
MAXILLOMANDIBULAR RELATIONSHIP							
ANB	0.4[A]	1.4	-0.1[AB]	1.1	-1.0[B]	1.5	0.012*
Wits	1.6[A]	2.2	0.9[A]	2.5	-0.9[B]	1.3	0.001*
NAP	-0.1	2.9	-1.0	2.4	-1.9	3.3	0.175
GROWTH PATTERN							
SN.GoGn	0.1	2.2	-0.3	2.3	-0.5	2.8	0.780
ANS-Me	2.1	2.8	2.3	3.0	4.1	4.2	0.171
SN.OccPlane	-1.9	2.7	-1.8	3.6	-1.6	3.0	0.956
MAXILLARY DENTOALVEOLAR COMPONENT							
1.NA	2.5	6.6	-1.5	5.8	1.6	2.8	0.064
1-NA	1.0[A]	2.3	-1.0[B]	2.0	0.8[A]	1.2	0.004*
1-PP	0.4	1.2	0.8	1.2	1.1	2.0	0.312
1.PP	2.8	6.7	-1.3	5.7	2.1	2.9	0.058
1-AP	0.9[A]	1.8	-1.4[B]	1.6	0.1[A]	0.9	0.000*
MANDIBULAR DENTOALVEOLAR COMPONENT							
1.NB	-1.6[A]	4.5	-5.1[B]	4.1	-2.1[AB]	3.8	0.025*
1-NB	0.3[A]	1.3	-2.1[B]	1.4	-0.1[A]	1.3	0.000*
1-MP	1.7[AB]	2.2	0.6[A]	1.8	2.4[B]	2.1	0.032*
1.MP	-1.5[A]	4.3	-5.3[B]	4.0	-3.1[AB]	3.8	0.023*
DENTAL RELATIONSHIPS							
Overbite	0.4	1.4	0.6	1.4	-0.2	0.7	0.153
Overjet	1.1[A]	1.8	1.0[A]	1.5	-0.4[B]	0.7	0.003*
Molar Rel	1.0[A]	1.2	1.6[A]	1.8	0.1[B]	2.3	0.047*
SOFT TISSUE							
UL-S Line	-0.1	1.4	-0.4	1.1	0.1	2.7	0.716
LL-S Line	-0.1	1.2	-1.2	0.8	0.4	3.4	0.078
G'.Sn.P'	-0.3	3.1	0.2	2.3	2.5	5.4	0.079

* Statistically significant at $p<0.05$. Different superscript letters represent statistically significant differences. € = Kruskal-Wallis test.

Table 5 - Intergroup comparison of OGS and PAR indexes.

	G1		G2		G3		P
	Mean	(SD)	Mean	(SD)	Mean	(SD)	
PAR1	28.1[A]	11.2	36.2[B]	8.1	21.1[A]	10.8	0.000 ʃ*
PAR2	3.7[A]	4.5	5.2[A]	2.7	25.0[B]	9.7	0.000 €*
PAR2-1	-24.4[A]	10.3	-30.9[B]	7.1	3.9[C]	6.5	0.000 ʃ*
%PAR	-87.6[A]	13.2	-85.7[A]	5.8	39.2[B]	71.6	0.000 €*
OGS	25.6	9.2	28.6	6.0	---	---	0.085 ¥

* Statistically significant at $p<0.05$. Different superscript letters mean statistically significant differences.
ʃ = ANOVA followed by Tukey tests. € = Kruskal-Wallis followed by Duncan tests. ¥ = t test.

DISCUSSION

Sample characteristics

Despite the limitation of a retrospective study, the group characteristics were similar, especially considering the difficulty in obtaining an untreated Class III malocclusion control group (Tables 1 and 3). Although there were significant differences regarding some cephalometric variables at baseline between control and treatment groups, one has to bear in mind that the changes in groups with similar malocclusions are the most important issues to be evaluated in this type of investigation. Few studies used a control group of untreated Class III patients.[3,4,7,12]

Cephalometric changes

The orthodontic treatments provided smaller mandibular advancement with respect to the control, especially in the extraction group, improving the maxillomandibular relationship (Table 4). Less protrusion or greater mandibular retrusion is evidenced in compensatory Class III orthodontic treatment in growing patients with orthopedic appliances, aiming at altering the skeletal growth pattern of the patients and either advance the maxilla forward or prevent the further forward growth of the mandible through a clockwise rotation, or both.[3,4,7] This effect is less evident in adult patients, where the maxillary dentoalveolar compensation is greater.[6,8] In the current study, the maxilla does not appear to have undergone major changes in relation to its initial positioning,[3] possibly due to the initial mean age of the sample. In order to obtain more maxillary skeletal effects, treatment must be instituted before the pubertal growth spurt.[1] The extraction group demonstrated greater maxillary anterior displacement restriction than the non-extraction group, probably due to the greater maxillary incisor retraction in order to close the extraction spaces.[20,21] Thus, it may be stated that minimal skeletal (maxillomandibular) changes were observed, while the dentoalveolar effects were more pronounced.

An increase in lower anterior face height (LAFH, ANS-Me) during Class III malocclusion treatment may result in a more retrusive position of the mandible, improving the sagittal relationship.[4,8] Although the LAFH increased with treatment and growth, no intergroup difference was observed, similarly to previous investigations.[7,12] Both treatment protocols did not cause significantly different changes in the growth pattern, compared with untreated subjects. Counterclockwise rotation of the occlusal plane has been observed in treatment with Class III elastics.[11,14] However, this was not observed in the treated groups.

Only the extraction group showed significantly greater maxillary incisor retraction than the other groups (Table 4). This was probably due to retraction of these teeth in order to close the extraction spaces. In Class III non-extraction mechanics in the maxillary arch, the incisors experience only small changes.[4,11,12,14,22] There are no studies specifically evaluating the extraction effects on the maxillary incisors in Class III treatment with fixed appliances.

The extraction group presented significantly greater mandibular incisor lingual tipping and retrusion, primarily in relation to the non-extraction group. In relation to the control group, it showed only significant retrusion (Table 4). Other studies with mandibular extractions observed incisor lingual tipping and retrusion[3] or only lingual tipping,[12] in relation to the control groups. There were significant improvements of the overjet and molar relationship in both treated groups, in relation to the control. It was fortunate that, despite the small changes in maxillary and mandibular incisors in the non-extraction group, significant improvements of these variables were possible. Another study showed similar changes in overjet and molar relation, without significant incisor changes.[4]

Even though these are compensatory treatments where facial impact is not as evident as in orthodontic-surgical treatment, changes of soft tissue may camouflage the skeletal Class III discrepancy, such as reduction of lower lip projection due to mandibular incisor retrusion[11,14] and the increase in facial convexity.[3,7,11,14] In the current study, although there were soft tissue changes, they were very discrete and statistically similar to the growth changes.

Occlusal changes

The extraction group had greater initial malocclusion severity, resulting from greater crowding (displacement), which weighted toward an extraction approach in this group (Table 5). The orthodontic treatments significantly improved the occlusion, when compared to the untreated group, which even had an increase in malocclusion severity, overtime.

The final PAR indexes in the treated groups were similar between the groups and also similar to previous reports on treated Class III malocclusion cases.[22] Because the initial malocclusion severity was significantly greater in G2, the amount of PAR reduction (PAR_{2-1}) was also significantly greater than in G1. However, the percentage of PAR reduction was similar in the treated groups G1 and G2 (%PAR). Orthodontic treatment is considered adequate when the index reduction is greater than 70%,[23] and therefore, treatment provided in the groups showed adequate quality.

The similar OGS in the treated groups confirm the results of the PAR_2, showing that both groups had similar quality of finishing (Table 5). No previous studies have compared the quality of occlusal finishing in Class III malocclusion treatments with or without extractions.

The American Board of Orthodontics states a case report with scores above 30 points will fail.[17,24] Some investigations in different universities showed mean OGS scores of 22.1[25], 22.4[26], 32.2[27] and 33.6,[28] comparable with the present results. In addition, the fact that the patients were treated in an university does not seem to influence the results, since studies report no differences between orthodontic treatment outcomes in university clinics and private practices.[29,30]

CONCLUSIONS

The effects of non-extraction and extraction Class III malocclusion treatments were:

» Orthodontic treatment with fixed appliances improved the sagittal relationships mainly with dentoalveolar changes.

» Extraction treatment presented greater maxillary and mandibular incisor retrusion, when compared to non-extraction treatment.

» Both extraction and non-extraction treatments significantly decreased the initial malocclusion severity in the same proportion.

» The final quality of orthodontic treatment was statistically similar between the extraction and non-extraction groups, with adequate occlusal outcomes.

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Indication of clear aligners in the early treatment of anterior crossbite: a case series

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Introduction: Anterior crossbite (AC) is defined as a reverse sagittal relationship between maxillary and mandibular incisors. According to an evidence-based orthodontic triage, the treatment need of AC is indicated if any occlusal interference is forcing the mandible towards a Class III growth pattern. Removable and fixed appliances have been suggested to correct AC.

Objective: The present report aims at presenting the benefits of an alternative therapy for the early treatment of anterior crossbite using clear aligners.

Methods: Two cases of anterior crossbite corrected using clear aligners in 8-years-old children are presented.

Results: In both cases, AC was successfully corrected within 5 months. At the end of the treatment, overjet and overbite were corrected. No major discomfort or speech impairment was noticed by the parents.

Conclusions: Due to the perceived shortcomings of alternative approaches, the use of clear aligners for correcting AC in mixed dentition should be considered as a comfortable and well tolerated appliance for young patients.

Keywords: Orthodontics, interceptive. Malocclusion. Orthodontic appliances, removable.

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

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INTRODUCTION

Early orthodontic treatment in mixed dentition is indicated to reduce or even eliminate the need for further orthodontic treatment by preventing functional problems or anomalies.

Anterior crossbite (AC) is defined as a reverse sagittal relationship between maxillary and mandibular incisors.

AC exhibits dental, skeletal, or functional aetiology or a combination of those aspects. AC of dental origin can arise by alteration of tooth inclination; skeletal AC involves a basal bone discrepancy in the sagittal plane. Functional AC (or pseudo-Class III) involves occlusion interferences that results in a mandibular displacement on closure.[1]

Orthodontists are often called upon to swiftly recognize and manage AC that may, if untreated, contribute to the development of a true Class III malocclusion and temporomandibular symptoms.[2] Chronic trauma may affect teeth with improper tooth inclination, resulting in periodontal problems, tooth wear, an increased risk of dental fractures, bruxism, and unfavorable oral habits such as lip biting.[3]

Another benefit of early correction of AC is the possibility of alleviating posterior crossbites induced by occlusal interferences and anterior mandibular shift.[4]

Currently, clinical management of AC can be achieved with multiple treatment options. According to Wiedel et al.,[5,6] appropriate criteria/requirements for an optimal orthodontic therapy are clinical effectiveness, long-term stability, positive cost-benefit ratio, and high patient acceptance, i.e., minimal perceived pain and discomfort.

Orthodontic fixed appliances (FA) include segmental techniques: 2 by 4 approach, with brackets bonded to the incisors and the first molars; and 2 by 6, including first molars and the 6 anterior (primary or permanent) teeth. To raise the bite, the fixed appliance treatment is frequently combined with a composite coverage temporarily bonded to the occlusal surfaces of posterior teeth.

Wiedel et al.[7] showed that the average duration of FA treatment, including the 3-month retention period, is 5.5 months, and a small number of minor complications (bond failures) is observed. Fixed appliance is the gold-standard treatment for children with whom compliance problems with wearing removable appliances (RA) are anticipated. As an impact of oral health-related quality of life, patients reported more discomfort eating different kinds of hard and soft food; poor oral hygiene can lead to decalcification and caries.[5]

Removable appliances include acrylic plates endowed with anterior springs that deliver light-continuous tipping movements to each incisor in an anterior crossbite.[2] The protrusion springs can be activated at each monthly visit until normal incisor overjet is achieved. The RA comprises a bilateral occlusal coverage, which allows the 'jumping' of the bite by increasing the occlusal vertical dimension. The RA must always be worn, except during meals and toothbrushing. If the patients' compliance in wearing the appliance is optimal, a successful correction of AC is accomplished in approximately 6.9 months.[7]

Patient-related complications (distortion/breakage/loss of the appliance, and low wear-time adherence) can be expected from a removable appliance, and patients report difficulties talking or doing school and leisure activities.[7]

In recent years, treatment approaches have been expanded with the use of clear aligners. The aesthetics, comfort, and oral hygiene of clear aligners are superior to conventional fixed appliances.[8,9] As it regards patient's perception, the impact of the clear aligners' treatment in daily activities (oral symptoms, functional limitations) is suggested to be lower than a multi-bracket treatment, especially in the first 6 months of therapy.[10]

This case series aims to present the results of early orthodontic treatment of two anterior crossbite cases performed with clear aligners.

MATERIAL AND METHODS

The present patients were clinically assessed and fully investigated regarding oral hygiene, general health along with any associated family history of Class III presentations. In accordance with the British Orthodontic Society Radiographic Guidelines (*https://www.bos.org.uk*), lateral cephalometric radiographs were obtained and analysed. Landmarks and measurements were validated by Shaw et al,[11] and all data were anonymized.

To diagnose any functional shift of mandible caused by AC with dental aetiology, the clinicians guided the mandible to seat the condyles into centric relation and evaluated any change in the molar and incisor relationship from centric occlusion to maximum intercuspation. This maneuver is also useful to estimate the sagittal and transversal jaw discrepancy based on clinical evaluation.

TREATMENT ALTERNATIVES

The main concern of both patients was the unaesthetic appearance of the maxillary central incisors, which were trapped behind the lower anterior teeth.

In discussing treatment alternatives, the orthodontists focused on three risk/benefit considerations:

» Fixed appliance treatment: this was disregarded as the patient and parents felt that this would worsen the aesthetic appearance and potentially affect the patient's self-esteem.

» Conventional removable appliance: this was disregarded as the patients and parents were concerned about the potential adverse effect on speech due to the palatal coverage.

» Invisalign® appliance: the use of clear aligners would meet the demand for aesthetic treatment among both children and parents. Absence of attachments and a 5-days-change protocol were adopted to achieve treatment goals with the less burden of care.

The virtual setup (ClinCheck®) can display a three-dimensional image with a prediction of the final position of teeth; based on our experience, the ClinCheck® itself is unlikely to have any influence of the duration of therapy, although it is potentially a very useful communication tool when obtaining consent.

The authors agree with patients and caregivers to treat this malocclusion and balance occlusal contacts with an aligner-based approach; the device was able to accomplish AC correction and intra-arch tooth alignment simultaneously.

ASSESSMENT

Case 1

An 8-years-old female presented with an AC from lateral to lateral with a 1-mm negative overjet. The parents reported the absence of familiarity for Class III malocclusion. Clinical examination revealed a forward shift of the mandible due to dental interferences. Skeletal analysis: lateral cephalogram, taken in maximum intercuspation with the mandible in its displaced position, revealed a skeletal Class I (Fig 1). The Wits appraisal depicted the underlying displacement of the mandible into a tendency towards Class III. Dental analysis: The patient showed a Class I bilateral molar relationship; the AC involved both upper and lower central incisors (Fig 1). Lateral cephalogram revealed a slightly palatal inclination of upper incisors, and a labial inclination of mandibular incisors.

Soft tissue analysis: the patient's soft tissue profile was slightly concave because of a small reduction of upper lip and a small protrusion of lower lip (Fig 1). The malocclusion was attributed to an altered eruption pattern of the permanent incisors, possibly resulting from dental crowding.

Figure 1 - Pre-treatment intraoral and extraoral photographs, and radiographic examinations.

Case 2

An 8-years-old male presented with an AC from lateral to lateral with a 1-mm negative overjet. The parents reported the absence of familiarity for Class III malocclusion. Clinical examination showed a lateral shift of the mandible due to dental interferences. Skeletal analysis: the lateral cephalogram, taken in maximum intercuspation with the mandible in its displaced position, showed a correct relationship between maxillary jaws (Fig 2).

Dental analysis: The patient showed a Class I bilateral molar relationship, and the AC involved both maxillary and mandibular central incisors (Fig 2). Lateral cephalogram revealed a slightly palatal inclination of the upper incisors, and a severe labial inclination of the left mandibular central incisor.

Soft tissue analysis: the patient's soft tissue profile was slightly concave due to a small reduction of the upper lip and a small protrusion of the lower lip (Fig 2). The malocclusion was found to be caused by an altered eruption pattern of the permanent incisors, possibly due to dental crowding.

TREATMENT

Treatment objectives

Treatment goals were:

» Andrew's third key: correct inclination of maxillary and mandibular teeth; absence of traumatic contacts.[12]

» Occlusal balance: balancing occlusal contacts to prevent functional shifts of the mandible.[12]

Treatment plan

Diagnosis and treatment planning determine the success of AC therapy:

» Adequate space in the arch to reposition the tooth: a concomitant maxillary arch deficiency may still justify the use of rapid maxillary expansion appliances to increase available space for maxillary incisors.[13]

» Usually, aligners' thickness provides overbite control during treatment to allow for the AC to be corrected: if the amount of vertical overbite is less than 2/3, the use of additional bite ramps should be advisable.[14]

» Occlusal relationships: to differentiate dental from skeletal crossbite, clinicians must guide the mandible into a centric relation and evaluate any change in the molar and incisor relationship from centric occlusion to maximum intercuspation, as well as estimate the relative size of the mandible compared with the maxilla.

» Castroflorio et al.[15] recommended the use of Power Ridges (Align Technology, Amsterdam, The Netherlands) to optimize torque control. In cases with AC involving lateral incisors, the use of attachments may prevent dangerous tip movements in cases when the anterior teeth are moved prior to permanent canine eruption as the roots of the lateral incisors can be displaced into the eruption path of the canine, with the resultant risk of root resorption of the lateral incisor.

AC should be slightly overcorrected to settle the incisors into the proper relationship.

Figure 2 - Pre-treatment intraoral and extraoral photographs, and radiographic examinations.

Treatment progress

Case 1

Maxillary and mandibular polyvinyl siloxane impressions were taken and sent to Invisalign®. A virtual planning of tooth movement in three dimensions was performed through ClinCheck® software (Align Technology, San Jose, CA, USA). The patient was instructed to wear each aligner 22 hours per day, even in school-time and social/sport activities. Twenty-eight aligners were scheduled, and a 5-day-change protocol was adopted.

Case 2

Fourteen aligners were scheduled, and a 5-day-change protocol was adopted. The overall treatment lasted 2.3 months. The child was motivated to maintain good oral hygiene. No discomfort or speech impairment were noticed by the parents.

Table 1 - Cephalometric values.

	Patient 1		Patient 2		Normal	
VALUES	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment	Mean	SD
SNA (degrees)	85	85	81	81	82	2
SNB (degrees)	82	82	78	78	80	2
ANB (degrees)	3	3	3	3	3	2
FMA (degrees)	30	28	22	22	25	3
U1-SN (degrees)	98	110	101	105	103	5
IMPA (degrees)	93	87	106	90	88	-
Wits (mm)	-4	-2	-0.5	1	2	2

RESULTS

Case 1

The overall treatment lasted 4.6 months. The child was motivated to maintain good oral hygiene. No discomfort or speech impairment were noticed by the parents.

At the end of the treatment, overjet and overbite were corrected. The small skeletal improvements observed (see Wits value, Table 1) may have resulted from the elimination of the mandibular shift and change in the incisor inclination, with subsequent remodeling of the overlying alveolar bone (Table 1). The inclination of upper and lower incisors was properly settled (Fig 3). Once proper overbite was achieved, the last aligners were worn night-time for 3 months after treatment, as vacuum formed retainers.

Case 2

At the end of the treatment, correct overjet and overbite were established. Moreover, the patient maintained harmonious relationships between the maxilla and the mandible (Table 1). The inclination of maxillary and mandibular incisors was properly settled (Fig 4). Once proper overbite was achieved, the last aligners were worn night-time for 3 months after treatment, as vacuum formed retainers.

Figure 3 - Post-treatment intraoral and extraoral photographs, and radiographic examinations

Figure 4 - Post-treatment intraoral and extraoral photographs, and radiographic examinations.

DISCUSSION

The purpose of this article was to highlight two cases of AC successfully corrected after therapy with clear aligners.

Due to the perceived shortcomings of alternative approaches, the use of clear aligners for correcting AC in mixed dentition should be considered as a comfortable and well tolerated appliance for young patients. This new technique allows young patients to participate in all their school and social activities without any aesthetic limitation. In fact, a removable device allows optimal oral hygiene, together with rigorous oral care. The use of clear aligners prevents the deterioration of periodontal status, the dental decalcifications during orthodontic treatment, and speech impairment due to the bulkiness of the removable appliance.[5,16]

Referring to the treated cases, the duration of therapy (below 5 months) was in line with conventional approaches. Li et al.[16] showed that the amount of activation force imparted by the aligner slowly decreases and plateaued within 5 days; therefore, the aligner change protocol was optimized, stressing out that a prolonged treatment may lead to a loss of compliance, especially in young patients.

The effectiveness and efficiency of this treatment lie in its ability to achieve dental torque movements with precision.[18] Furthermore, the occlusal vertical dimension is increased by aligners' thickness, which prevents contacts and provides an adequate vertical clearance for a feasible crossbite correction.[19] To avoid the use of an additional retention appliance, the final aligner can be used for three months after the end of the treatment to retain the corrected tooth positions.[20]

Some limitations of this report should also be considered. Although the results were encouraging, there is a need for evidence to draw guidelines for clinical practice and compare the perceptions of the patient's pain and discomfort for the correction of AC with clear aligner, FA, and RA treatments.

The cost of the aligners cannot be averaged as it is fairly dependent on the company and the number of cases treated by the orthodontist. According to the prices reported by Wiedel et al,[5] the material cost of clear aligners (above €700) is conceivably more than FA (€32) and RA therapy (€227). The cost difference is reduced if the final aligner is also used as a retainer, possibly compensating the necessity of Hawley and vacuum formed appliances.[5]

Another drawback is that a nearly full-time wear of the aligners is required to achieve an effective and efficient resolution of this malocclusion. Since clear aligners are removable devices, the orthodontic correction is entirely based on patient's compliance.

CONCLUSIONS

It is important to highlight the importance of clear aligners as an alternative to correct AC in mixed dentition. Notably, this technique may be easily accepted by patients who feel distressed by a fixed orthodontic treatment. Unlike removable appliances in the maxillary arch, clear aligners blend seamlessly with crown anatomy, thus avoiding the unsightly discomfort of the palatal coverage.

Short treatment time and comfortable orthodontic treatment receive positive feedback from parents and caregivers, who seek a rapid improvement in their children' aesthetics and function.

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Conception or design of the study: RP, PG. Data acquisition, analysis or interpretation: : RP, ES, FG, AC, SM, PG. Writing the article: RP, PG. Critical revision of the article: RP, ES, FG, AC, SM, PG. Final approval of the article: RP, ES, FG, AC, SM, PG.

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Von Mises stresses on Mushroom-loop archwires for incisor retraction: a numerical study

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Objective: To perform a numerical simulation using FEM to study the von Mises stresses on Mushroom archwires.

Methods: Mushroom archwires made of titanium-molybdenum alloy with 0.017 x 0.025-in cross-section were used in this study. A YS of 1240 MPa and a Young's modulus of 69 GPa were adopted. The archwire was modeled in Autodesk Inventor software and its behavior was simulated using the finite element code Ansys Workbench (Swanson Analysis Systems, Houston, Pennsylvania, USA). A large displacement simulation was used for non-linear analysis. The archwires were deformed in their extremities with 0° and 45°, and activated by their vertical extremities separated at 4.0 or 5.0 mm.

Results: Tensions revealed a maximum of 1158 MPa at the whole part of the loop at 5.0mm of activation, except in a very small area situated at the top of the loop, in which a maximum of 1324 Mpa was found.

Conclusions: Mushroom loops are capable to produce tension levels in an elastic range and could be safely activated up to 5.0mm.

Keywords: Mushroom archwires. Finite Element Method. Titanium-molybdenum alloys.

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INTRODUCTION

Malocclusion treatment requires a treatment plan considering a 3-D approach, since dental arches can have an elliptic, hyperbolic, parabolic, U-shaped or a V-shaped form. Also, in dental movement, teeth must be considered in a 3-D spatial position. The 3D Finite Element Analysis (FEM) has been widely used for the analysis of complex structures under different loads and conditions,[1-2] because one of the most important parts of numerical analysis is to minimize loss of performance of a structure. Also, it allows to create, develop and test the mechanical behavior of many appliances not only in medicine, but also in dentistry, engineering and other biomedical fields of interest, as structural analysis, heat transfer, mass transport, fluid flow and electromagnetic force.[1] Once teeth are attached in the periodontal ligament, a complex force system is created during orthodontic treatment. Many papers deal with periodontium modeling, i.e., gingiva, periodontal ligament, alveolar bone and cementum, to study teeth movement in all space positions, but modeling is complex due to anatomical differences among patients.[1-2] Orthodontic appliances should be developed to move teeth with a desired force system (Fx, Fy and Mz) capable to produce controlled teeth tipping, intrusion or extrusion, during movement[3]. In orthodontics, closing loops are used to retract teeth in cases where spaces need to be closed to obtain a stable occlusion, considering that many spaces are due to therapeutic extraction cases in dental protrusion treatment. Closing loops have been studied from the first design from Bull,[4] who developed a canine retraction spring made with stainless steel. Later, Burstone[5] developed T-loop closing loops made with titanium-molybdenum alloy. Among the different geometries, T-loops were the most studied at moment. T-loops have been verified in holographic studies, also experimentally, numerically and clinically along the years, regarding gable bends effects, loop position, cross-section, relaxation stress,[6] and the behavior of the force system.[3,5] Closing loops archwires have been studied experimentally[2,3] and numerically[3] to obtain tension levels and the force system, i.e., three-dimension forces (Fx, Fy and Fz), rotational tendency (Mx, My and Mz) and consequently the M/F ratios (M/F ratios are relevant to know the tooth movement tendency). From the classic studies on closing loops to the present date, many designs have been created and some of them had their tension levels evaluated through von Mises yield criterion. The von Mises yield criterion through FEM predicts the stress (yielding of materials) on ductile materials over a material under complex loading (multiaxial loading conditions). Some years ago, a modified T-loop called Mushroom loop archwires (ML archwires) was developed[7] to retract incisors with controlled torque and anchorage control, since this archwire avoids posterior teeth to move forward, resulting in anchorage loss. If molars move mesially, the extraction spaces may be lost and dental protrusion may not be perfectly corrected.[7-12]

No study at this time verified the tension levels on Mushroom archwires geometry, but only clinical studies were performed showing good results.[7,9] Thus, the present study aims to study using FEM the von Mises stresses over a 3-D Mushroom loop design after activation.

MATERIALS AND METHODS

Tridimensional model

The archwire was modeled in AutoDesk Inventor software and its behavior was simulated using the finite element code Ansys Workbench (Swanson Analysis Systems, Houston, Pennsylvania, USA). The FEM consist in splitting the body into sub-regions, the FEs. The equations pertaining to each element are joined to preserve continuity and obtain an equation that represents the entire body. In the static analysis of stress-strain, the equation $[K] x \{u\} = \{F\}$ represents the body to be analyzed. The 'K' is the stiffness matrix, 'u' is the nodal displacement vector, and 'F' is the nodal force vector. After finding the nodal displacements $\{u\}$ through the solution of the algebraic system shown in equation above, the stresses and efforts on the body may be evaluated. Thus, the matrix $[K]$ depends on the vector $\{u\}$, characterizing a non-linear system of equations due to large displacements characteristics. The activation was performed in increments of 1.0 mm in the horizontal direction up to 5.0 mm, and considered maximum when, at any point, the archwire material reached its YS (Yield Strength) limit and, consequently, suffered permanent deformation, and the simulation process was terminated. Figures 1A and 1B show the isometric view. Figure 2 depicts the loop dimensions with angular and linear details. The archwire is characterized by 0.432 x 0.635 mm (0.017 x 0.025-in) cross-section and made by titanium-molybdenum alloy with a Modulus of Elasticity (E) of 69 GPa (10 x 10^6psi) and a YS (σe) equal to 1240 MPa (180 x 10^3psi).

Tension analysis

Stress analysis is performed to verity if a ductile material is working in the elastic regime, and serves as a parameter to define the maximal admissible activation, since plastic deformation should be avoided during maximum distortion energy criterion, according to von Mises criterion theory. A three-dimensional simulation obtained by FEM search to evaluate tension levels that rise in the archwire body after activation. ML archwire should work in elastic range, i.e., should not surpasses the YS after pre-activation and after activation. This study was restricted to consider only the four anterior brackets due to the degree of stress-strain on the loops. Four blocks simulated the incisors brackets keeping the same interbracket distance. Table 1 shows the material mechanical properties.

A large displacement for non-linear analysis was used for simulation. The archwires were deformed in their extremities with 0° and 45°(Fig 3) and the loop was activated. For activation, the vertical extremities of the loop were separated at 4.0 or at 5.0 mm. Initially, only pre-activation was considered (vertical extremities separated for 2.5mm, anterior torque and gable bends inserted). Figure 4 shows the archwire activated. FEM performed a convergence analysis of maximum tensions controlling the maximum element size, assigning different sizes 0.60, 0.55, 0.50 and 0.45 mm type tetrahedral 3D quadratic.

RESULTS

Table 2 shows the maximum tension values for each element number and the maximum element size. As maximum tensions increase significantly in mesh 3 and decreases in mesh 4, it was observed a convergence in mesh 3 that was adopted in this model. Figure 5 shows the detail of the region where the convergence study was done. It is important to emphasize that although the tension reaches the peak of 1324 MPa that surpass the material's YS, this value found at 5.0 mm of activation is situated at the top of the loop in a very small punctual area (Fig 5) while a more accurate analysis of the different resulted tensions revealed a maximum tension of 1158 MPa at the whole part of the loop. The von Mises stress analysis revealed that the maximum tensions are not significant for 4.0mm and 5.0mm of activation.

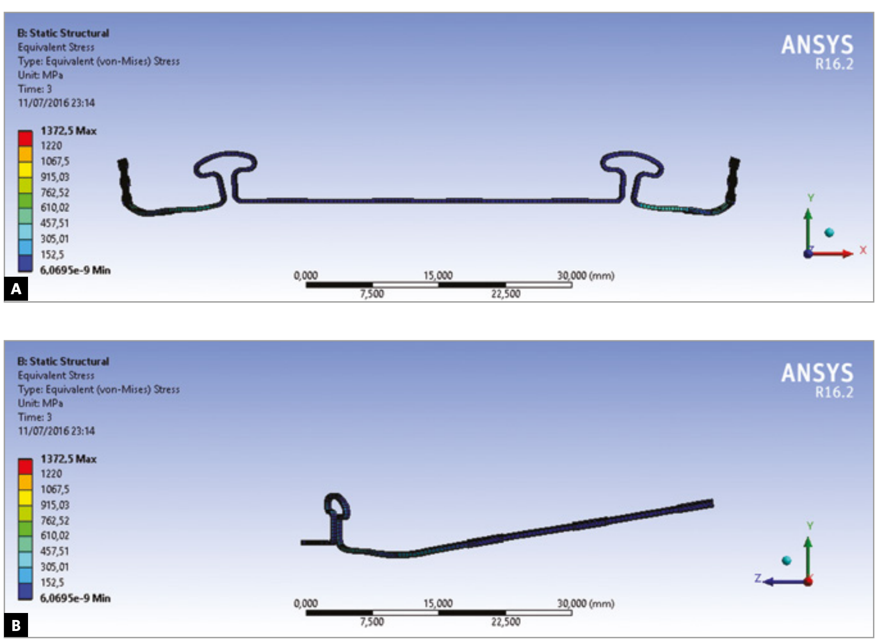

Figure 1 - A) Mushroom archwire isometric frontal view. B) Mushroom archwire isometric sagittal view.

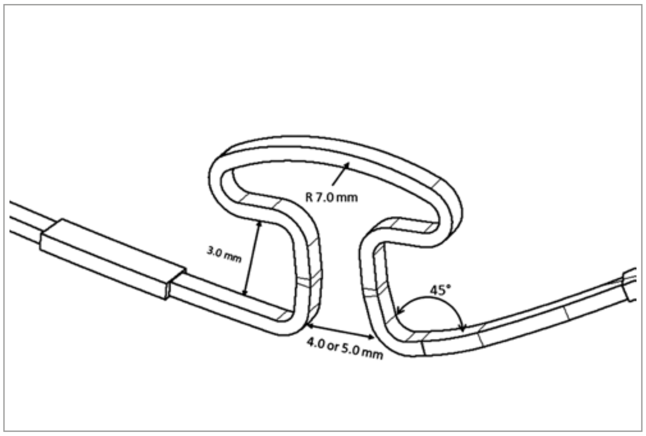

Figure 2 - Mushroom angular and linear dimensions.

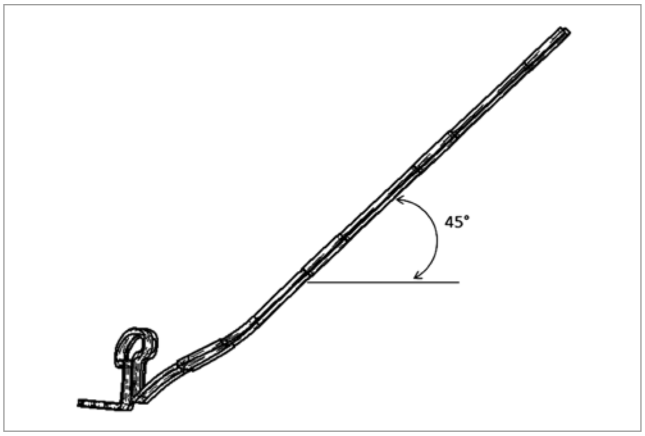

Figure 3 - Mushroom archwire and gable bend. At left of the loop, detail of the lateral incisor bracket. At right side, distal extremity, with a gable bend of 45 degrees.

Table 1 - Wire material mechanical properties.

Modulus of elasticity (E)	69 GPa
Yield stress (σe)	1240 MPa
Poisson's ratio	0.3
Bulk modulus	57.5 GPa
Shear modulus	26.54 GPa

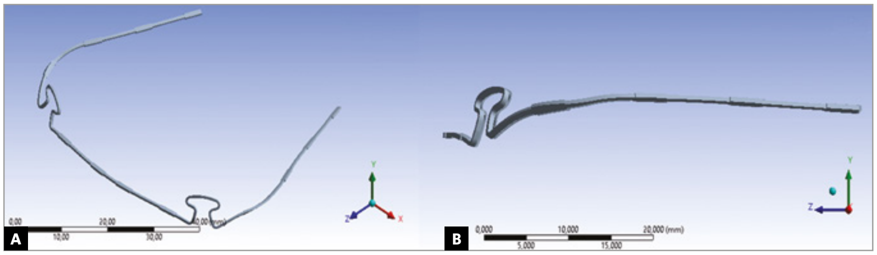

Figure 4 - A) Isometric view. B) Detail in anterior view with brackets.

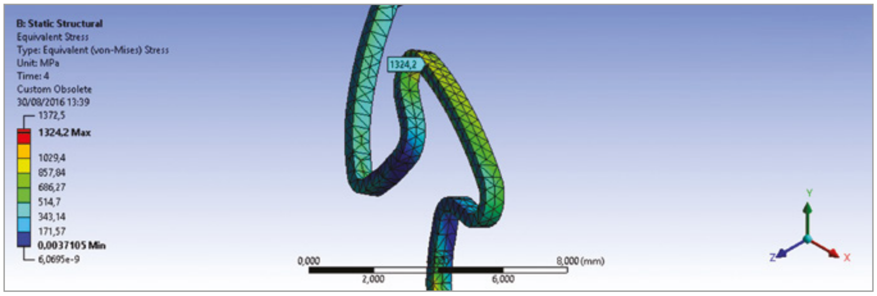

Figure 5 - Configuration at maximum tensions.

Table 2 - Convergence study.

Mesh	Maximum face size (mm)	Number of elements	Number of nodes	Maximum Stress (MPa)
1	0.60	4258	9771	1221.10
2	0.55	5399	12230	1220.10
3	0.50	6455	14116	1324.20
4	0.45	8197	17410	1203.80

DISCUSSION

The present paper evaluated the von Mises stress over a 3-D Mushroom prototype using AutoDesk Inventor software considering the von Mises criterion theory.

A three-dimensional simulation obtained by FEM was performed. ML archwires with CNA Beta III wire material (0.017 x 0.025-in) are very important appliances to retract anterior teeth with torque and anchorage control.[7,9-12] Closing loops incorporated in archwires helps to control anterior torque over incisors during retraction, but they should work in an elastic range to develop a desired force system. Besides spring geometry, properties as low load deflection rates, adequate spring gradient (spring rate) and working range should be considered in closing loops.[13-21] Also, torque control and gable bends are important second-order bends to avoid incisors to move lingually during retraction and posterior anchorage loss, respectively. Retraction closing loops should have a low load/deflection rate and work in an elastic, range to prevent plastic deformation. If the material enters in the plastic regime (surpass YS), the retraction spring cannot develop the minimum load to produce teeth movement.[13] In this research, ML archwire was evaluated by FEM to know the von Mises stresses resulted from pre-activation and activations. A titanium-molybdenum material with a Yield Strength (YS) of 1240 MPa and a Modulus of Elasticity (E) of 69 GPa was used. It was verified in the present study that the ML archwires are capable to produce safe tensions along the spring body and could be activated up to 5.0 mm without risk of loop deformation.

In a FEM study[13] focusing on verifying the von Mises stresses in Delta retraction springs (DRS, TMA, 0.016 x 0.022-in) using numerical and experimental methods, it was concluded that the springs could be activated up to 7.0 mm without surpass the YS. Also, Tear Drop loops were verified[14] experimentally and numerically concerning the force system and the stress along the loops (SS, 0.019 x 0.025-in). It was found high tension levels at the top of the loop (1201-1352 N/mm^2). Another paper[15] verified the behavior of DRS to know the von Mises stresses comparing prototypes with and without helicoids inserted on the top of the springs. The authors concluded that the insertion of helicoids decreases the deflection rates according to early studies.[5,20-22] In the present paper, even though the YS obtained (1324 MPa) surpass the material YS (1240 MPa), this value does not represent a significant tension because plastic deformation occurs only at a very small localized point (upper part of the loop). A more accurate analysis of the different tensions obtained over the spring revealed that the maximum tension is about 1158 MPa also at the top of the loop at 5.0 mm of activation. Studies concerning the von Mises tensions show that the higher tensions normally occurs at horizontal legs near the attachments (brackets or molar tubes) and in the superior part of the loops due to energy concentration.[13,15,16] ML archwires are a modified version originated from T-loops developed by Nanda[23] aiming to obtain more flexibility during the controlled retraction or translation of the four incisors, after the canine retraction (two-step procedure).[7] For an ideal tooth movement of the anterior teeth, the translation movement should have a M:F ratio of approximately 10:1.[7,23]

In the present study, a titanium-molybdenum material was considered with the same mechanical properties of TMA wires. The prototypes studied, as well as the Mushroom arches, had their upper portion rounded and were pre-activated at their vertical extremities, spaced 2.5 mm apart. Vertical extremities could be activated from 4.0 mm up to 5.0 mm to produce effective anterior torque to prevent incisors to tip lingually during retraction. Also, incorporated gable bends of 45 degrees in their extremities are made to avoid anchorage loss in the posterior segment. Titanium molybdenum with a nominal composition of 79% Ti, 11% Mo, 6% Zr and 4% Sn has been used clinically. CNA Beta III alloys are nickel-free, and prevents allergies in some patients, have a good range and are about 42% less stiff than stainless steel.[23] Many papers show case reports[8-12] dealing with CNA Beta III alloys, but no study demonstrates experimentally or numerically what occurs in the loop body with Mushroom geometry neither their force system after activation. In simulations, the results represent the behavior of the same object that is based on its theoretical model, so there is no variation in the material behavior. On the other hand, in the experimental method, the real behavior of an object and error must be verified statistically in order to certify that this error lies within certain limits. Further experimental studies are necessary to obtain the moments (Mx, My and Mz), forces (Fx, Fy and Fz) and the M/F ratios.

CONCLUSIONS

» Mushroom loop 0.017 x 0.025-in archwires are capable to produce tension levels in an elastic range and could be activated safely up to 5.0mm.

» Tensions revealed a maximum of 1158 MPa at the whole part of the loop at 5.0mm of activation, except in a very small area situated at the top of the loop, in which a maximum of 1324 MPa was found.

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Evaluation of zinc-oxide nanocoating on the characteristics and antibacterial behavior of nickel-titanium alloy

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Objective: To investigate the effect of ZnO nanocoating on mechanical properties of NiTi orthodontic wires and antibacterial activity.

Methods: 0.016x0.022-in NiTi orthodontic wires were coated with ZnO nanoparticles using an electrochemical deposition method with three electrodes system in 0.1M $Zn(NO_3)_2$. Mechanical properties and frictional resistance of the coated wires were investigated using an universal testing machine. Antibacterial effect of ZnO coating was also investigated.

Results: A stable adhered ZnO nanocoating on NiTi wires was obtained. The coated wires have a significant antibacterial activity against *S. aureus*, *S. pyogens* and *E. coli*, and a reduction of frictional forces by 34%.

Conclusion: ZnO nanocoating may improve the antibacterial effects of NiTi wires and reduce the frictional resistance. Coating may be implanted in orthodontic practice for faster and safer treatment.

Keywords: Friction resistance. Antibacterial agents. NiTi orthodontic wires. ZnO nanoparticles.

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INTRODUCTION

Nickel-titanium (NiTi) wires have unique properties compared with other types of wires. NiTi wires can generate light forces in a large range of action, so they are considered to be the ideal orthodontic archwires for the initial stage of comprehensive orthodontic treatment. The ability of the wire to slide along the bracket is essential for proper alignment and leveling in this stage.[1] However, the main disadvantage of NiTi wires are surface roughness and high friction coefficient, which result in high frictional resistance.[1,2] Consequently, higher orthodontic forces would be needed to overcome resistance to sliding and to achieve the desired tooth movement.[2,3] Such excessive forces can increase the treatment duration, raise the risk of anchorage loss, undesirable tooth movement and root resorption.[4,5]

The overall resistance to sliding is the sum of frictional resistance and binding. Binding occurs when contact points are formed between the edges of the bracket and wire, and when the angle between them exceeds the critical amount.[6] Resistance to sliding is affected by some factors including wire and bracket material and surface characteristics. Various techniques are proposed to overcome resistance to sliding, including the use of different alloys, surface treatment, altering size and shape of the wire and bracket, and coating with different materials such as Teflon, inorganic fullerene-like nanoparticles of tungsten disulfide and carbon nitride film.[6,7,8] The friction present during sliding mechanics represents a clinical challenge to the orthodontists because high level of fiction may reduce the effectiveness of the mechanics, decrease tooth movement and further complicate anchorage control.[9] Reduction of friction between bracket and archwire can improve the orthodontic forces up to 50% and significantly facilitate tooth movement. It is also assumed to decrease treatment duration and the risk of apical root resorption.[10]

On the other hand, contact between orthodontic wires and brackets provides additional sites for microorganism binding and colonization.[11] Demineralization of enamel and formation of white spot lesions (WSLs) are one of the most common side effects in fixed orthodontic treatments, with an estimated prevalence of 38% in the first six months and 50% at the end of the fixed orthodontic therapy, and may persist 5 years after the appliance removal. The major responsible factor for the formation of WSLs and dental caries is *Streptococcus* species.[12,13]

Many previous studies have investigated the antibacterial characteristics of coated orthodontic wires with different agents, including a photocatalytic titanium oxide (TiO_2) with silver and copper oxide nanoparticles.[13,14]

This study aimed at coating NiTi wires with ZnO nanoparticles by electrochemical deposition. In this process, a thin and tightly adherent coating of metal oxide was deposited onto the surface of a conductor substrate by simple electrolysis in a solution containing the desired metal ion or its chemical complex. Electrochemical deposition has the advantage of providing corrosion resistance to the coated metals, thereby protecting the original material. In addition, the low cost and the ability to improve mechanical characteristics of coated metals are appreciated. It was also claimed that nanoparticles (NPs) may provide a new strategy for treating and preventing dental infections.[15] The large surface area and high charge density of NPs enable them to interact with the negatively-charged surface of bacterial cells, resulting in enhanced antimicrobial activity.[16] Moreover, NPs combined with polymers or coated onto biomaterial surfaces was found to exhibit superior antimicrobial properties in the oral cavity.[17]

The goal of this study was to deposit ZnO nanocoating on NiTi wires and evaluate the antibacterial resistance and the effect of nanocoating on frictional resistance of NiTi wires.

MATERIAL AND METHODS

Preparation of NiTi wires

Rectangular 0.016 x 0.022-in orthodontic wires commercially available (Ortho-Organizer, FL, USA) were ultrasonically cleaned in an absolute ethanol solution for 10 minutes at 37°C, followed by immersion of the wires in a 4 M potassium hydroxide KOH at 100°C for 30 minutes using magneto-agitator device.

Coating wires with ZnO nanoparticles

Aqueous electro-deposition was performed using 0.1 M zinc nitrate Zn $(NO_3)_2$ that was prepared by adding 2.97 g of zinc nitrate to 100 ml of distilled water, then adding aqueous ammonia to the solution to make it alkaline, under vigorous mixing.

Electro-deposition was performed in three electrodes system in a single compartment cell (Fig 1):

» Platinum disk (3.14 mm^2) works as the counter electrode.

» NiTi wires act as the working electrode.

» Referencing electrode as SCC (saturated calomel electrode).

Potentiostat-galvanostat as power supply with applied potential ranging from - 0.91 to -1.1 volt for 2-3 minutes.

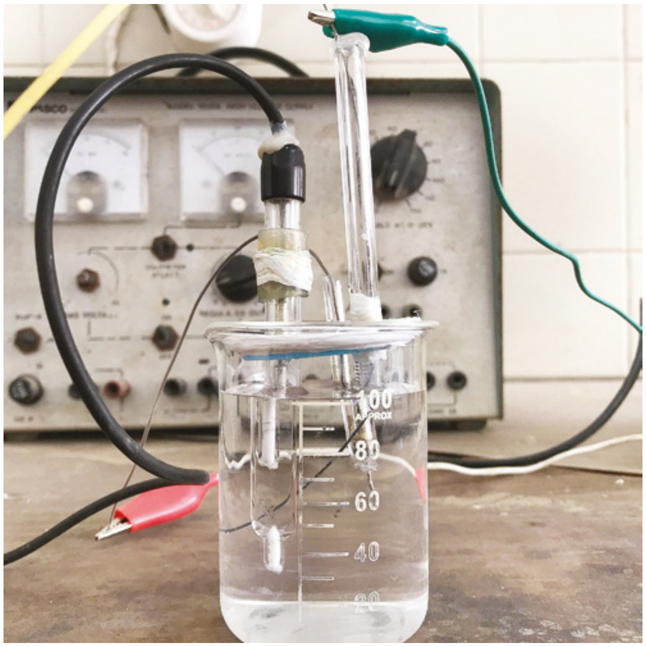

Figure 1 - Three electrodes system in a single compartment cell.

Characterization of ZnO nanoparticles

The ZnO nanoparticles morphology and chemical composition of the particles were analyzed using scanning electron microscope and EDAX analysis.

Antibacterial activity of the ZnO nanoparticles coated wires

Antibacterial activity of the coated wires was assessed against *Streptococcus pyogenes* (Gram-positive), *Staphylococcus aureus* (Gram-positive) and *E. coli* (Gram-negative). Twelve plates each containing 2 cc of nutrient agar were prepared under a septic condition then the plates were incubated for 24 hours at 37°C.

Both coated and non-coated groups were tested for antibacterial activity. Twenty four wires were transferred to the plates, four plates for each type of bacteria. Bacterial growth inhibition was thus evaluated around the wires tested.

Friction test

Friction measurements were developed to simulate sliding movements within a bracket system, and used for measuring frictional resistance using a Universal Testing Machine (UTM) (Lloyd LR 5K- England), composed by a frame for machine supporting, load cell for measurement of the forces, cross head, test fixtures and output devices. The machine was connected to a computer for force analysis and printing of the results. Twenty pieces of wire were prepared for friction test. To simulate the sliding of the tooth across the archwires, 0.022-in slot stainless steel brackets (Ortho-Organizer, FL, USA) were used. The wires were connected to brackets by elastomeric ligatures. Brackets were bonded to the metal bars using cyanoacrylate bonding agent, then the metal bars were attached to the base of the universal testing machine.

The wires were then pulled out from the brackets at a cross-head speed of 10 mm/minute with deflection limit of 3 mm and the load cell was calibrated between 0 and 10 N. After each test, the sample was replaced by another one, and finally all recorded data were collected and subsequently statistically analyzed.

Statistical analysis

Data were analyzed with SPSS version 21. The normality of data was first tested with Shapiro-Wilk test. Continuous variables were presented as mean ± standard deviation (SD) for parametric data. The two groups were compared with Mann-Whitney test (non-parametric data), while ANOVA test was used to compare more than two groups (parametric data). Comparison between groups was performed by *post-hoc* LSD test.

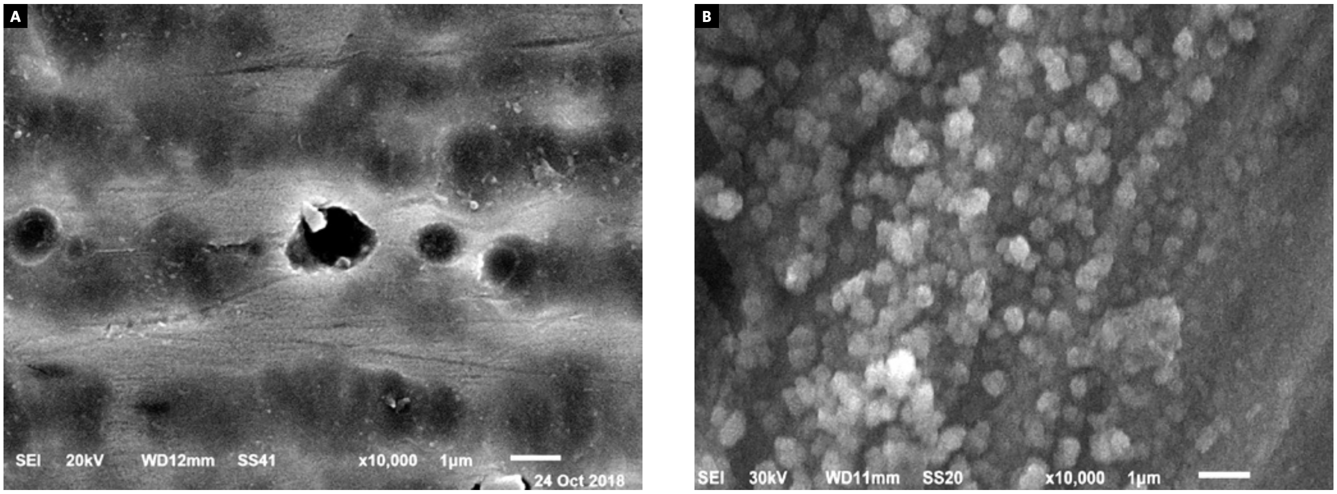

Figure 2 - **A**) Photomicrograph of non-coated NiTi wires, **B**) Photomicrograph of ZnO nanocoating on NiTi wires.

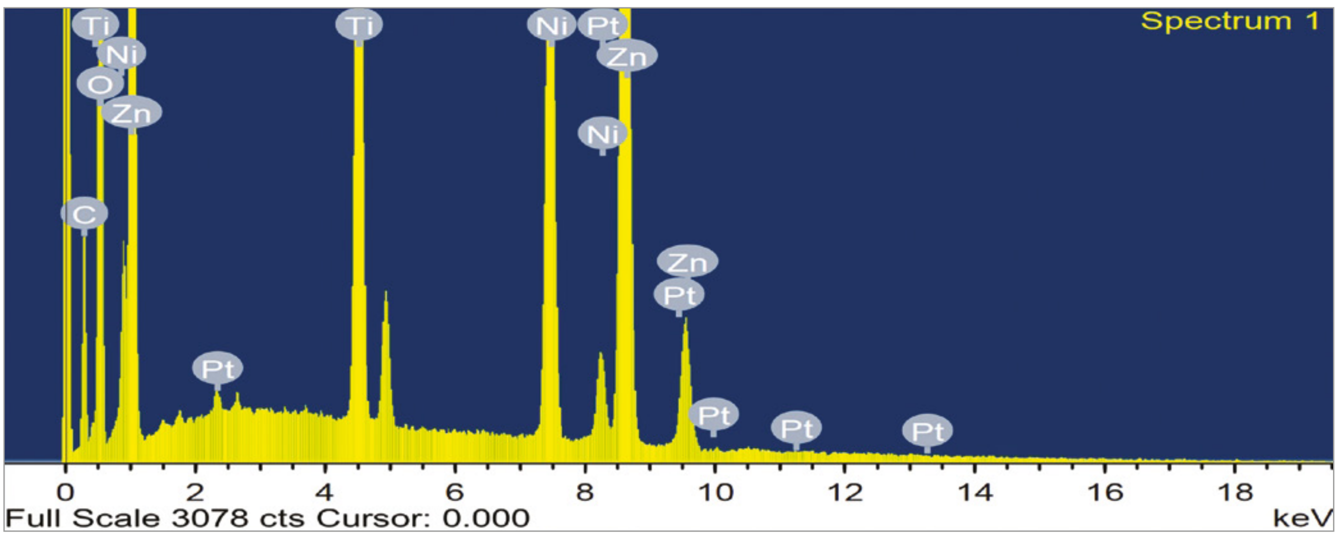

Figure 3 - EDAX analysis of ZnO nanocoated NiTi wires.

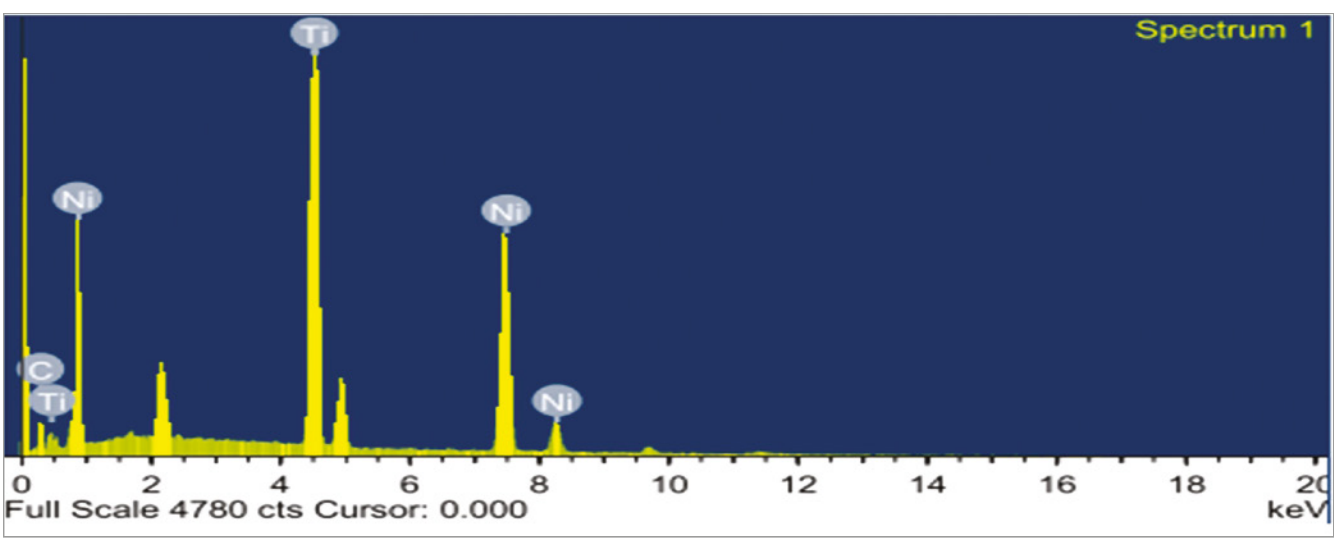

Figure 4 - EDAX test for uncoated NiTi wires.

RESULTS

Characteristics of the ZnO nanoparticles

Scanning electron microscope of the ZnO nanoparticles coated wires demonstrated a homogenous layer of nanoparticles on the wire (Fig 2). EDAX analysis demonstrated the formation of ZnO nanoparticles on the wire surface (Zn=20% by weight, O=45% by weight, Ti=7.15% by weight and Ni=8.81% by weight), as shown in Figure 3 and Table 1. EDAX analysis of non-coated NiTi wires (Ni=48.62% by weight, Ti=40.91% by weight and C=10.47% by weight) is show in Figure 4 and Table 2.

Antibacterial activity test

While non-coated wires showed bacterial growth around the wires, coated wires showed no bacterial growth. None of ZnO-coated wires presented bacterial growth after incubation for 24 hours at 37°C regarding all types of bacteria used: *S. aureus* (Gram-positive), *S. pyogenes* (Gram-positive) and *E. coli* (Gram-negative). Inhibition zone was formed around all ZnO nanoparticles coated wires with all types of bacteria. Moreover, ZnO nanoparticles promoted more antibacterial effect on Gram-positive bacteria than Gram-negative bacteria (Table 3).

Table 1 - Atomic% and weight% of the elements of ZnO coated wires.

Element	Weight%	Atomic%
C K	16.26	27.97
O K	45.92	59.29
Ti K	7.15	3.08
NI K	8.81	3.10
Zn K	20.14	6.36
P t L	1.72	0.18
Total	100.00	

Table 2 - Atomic% and weight% of the elements of non-coated NiTi wires.

Element	Weight%	Atomic%
C K	10.47	34.13
Ni K	40.90	33.44
Ti K	48.62	32.43
Total	100	100

Table 3 - Mean diameter of inhibition zones around coated wires in different bacteria.

Type of bacteria	Mean	SD	Minimum	Maximum
Staph. aureus	4.25	0.49	3.70	4.80
Strepto. pyogens	6.25	0.64	5.50	7.00
E. coli	3.57	0.43	3.00	4.00
ANOVA Test	27.34			
P- value	<0.001*			

Table 4 - Comparison of Load at Limit (N) among coated and uncoated groups.

Load at Limit (N)	Coated group (n=15)	Uncoated group (n=10)	Mann-Whitney	P- value
Mean	1.169	1.568		
SD	1.257	1.017		
Median	0.872	1.517	1.33	0.183
Minimum	-0.78	0.26		
Maximum	3.98	3.73		

Friction test

Table 4 shows that the presence of ZnO nanoparticles on the wires has decreased the mean frictional forces in the coated wires by 34%, compared with the non-coated wires (1.169 and 1.568 N, respectively). The coated wires showed a lower median frictional load (0.872 N) than uncoated wires (1.517 N), although no statistical significant difference could be found ($p = 0.183$).

DISCUSSION

NiTi archwire are the first choice for initial treatment as they provide light and constant forces for long periods without requiring several activations. However, they have great disadvantages due to the high friction coefficient. In addition, bacterial accumulation also occurs due to surface roughness. In this context, many attempts were done to overcome these problems and also to make orthodontics more esthetic. In this study, ZnO nanoparticles were used for coating of NiTi wires, characterized and investigated for their anti-bacterial properties, and friction resistance.

Chemical analysis of the coated wires demonstrated the formation of ZnO nanoparticles on the wire surface (O_2=59.29 atomic%, Zn=6.36 atomic%, Ti=3.08 atomic% and Ni=3.10 atomic%). The present findings corroborate the results obtained by Kachoei et al.[14] The EDS analysis of the coated wires confirmed that the wires consisted of nickel, titanium, zinc and oxygen.

Surface topography of the ZnO nanocoating reveled homogenous layer of spherical shaped nanoparticles ranging from 40 to 60 nm in size on the wire surface. These results agree with Kachoei et al.[14] Scanning electron microscope images showed spherical ZnO nanoparticles with particle size ranging from 25 to 30 nm. Behroozian et al.[19] used SEM technique to evaluate surface pattern of ZnO nanoparticles deposition and showed the presence of spherically shaped ZnO nanoparticles on the wire. Kachoei et al.[20] confirmed a uniform coating of spherical shaped ZnO nanoparticles on stainless steel wires with narrow size distribution ranging from 40 to 45 nm.

Antibacterial characteristics

The incidence of WSLs and surface demineralization were noticed to happen in the first months of treatment and is initiated by *Staphylococcus* strains.[12,13] Many attempts in previous studies were made to prevent WSLs, by brackets and wires coating with antibacterial agents. However, only few studies have explored the antibacterial effect of ZnO nanoparticles in orthodontic applications. The results of the present study revealed that ZnO nanoparticles had a significant antimicrobial activity against various bacterial strains: *S. pyogenes* (Gram-positive), *E. coli* (Gram-negative) and *S. aureus* (Gram-positive). ZnO nanoparticles have more bactericidal effect on Gram-positive bacteria than Gram-negative bacteria, according to the inhibition zones pattern noticed (Table 3). The antibacterial mechanism of NPs can be roughly divided into three types, although the specific mechanism of action is not yet clear. First, interacting with peptidoglycan cell wall and membrane, causing cell lysis; then, interacting with bacterial proteins and disrupting protein synthesis; and finally, interacting with bacterial (cytoplasmic) DNA and preventing DNA replication.[21,22,23] The results of this study are in agreement with the results obtained by Ramazanzadeh et al,[18] who studied the antibacterial effect of brackets coated with ZnO and CuO nanoparticles against *S. mutans,* and observed that the antibacterial effect of the coated brackets with ZnO-CuO and ZnO nanoparticles on *S. mutans* was excellent, since after two hours the bacterial count was reduced to zero. The coated brackets with ZnO nanoparticles ranked second, although in comparison with control group caused significant reduction of *S. mutans*, it could not reduce the population of *S. mutans* to zero even after 24 hours.[15] Azam et al.[24] compared the antibacterial activity of CuO, ZnO and Fe_2O_3 nanoparticles against Gram-positive (*S. aureus* and *P. aeruginosa*) and Gram-negative (*E. coli* and *Pseudomonas*) bacteria, and reported that ZnO nanoparticles have the best antibacterial effect and Fe_2O_3 nanoparticles exhibit the lowest activity. Although Cu nanoparticles have unique chemical, biological and physical properties and low cost of preparation, the rapid oxidation in air limits their application in orthodontics.[25]

It was suggested that the toxicity of antimicrobial nanoparticles is affected by many factors as dosage, type, particle size, distribution, duration of action, concentration and interaction with other compounds.

Nanoparticles can enter the body and accumulate in the organs due to the small particle size. No study could be found; however, proving the cytotoxicity of nanoparticles on human beings. Although some few studies have been done to explain the cytotoxicity of antibacterial nanoparticles, there are no uniform indicators to standardize the toxicity of nanoparticles.[26]

Mechanical properties

This study evaluated the effect of ZnO nanocoating of NiTi wires on frictional forces. The result showed a decreasing effect in friction resistance to sliding in the ZnO coated wires, compared to non-coated wires. The mean total frictional forces were estimated to be 1.169 N for coated wires and 1.568 N for uncoated wires, demonstrating a reduction of 34% after nanoparticles coating. These results coincide with the results obtained by Kachoei et al,[14] who showed that the presence of ZnO nanoparticles coating on the wires has significantly decreased the frictional forces up to 21%. The frictional force was recorded as 1.227 N in the coated wires and 1.642 N for the non-coated wires. Also, Behroozian et al.[19] studied the ZnO nanoparticles coating effect on the frictional resistance between ceramic brackets and orthodontic wires, and reported that the ZnO nanoparticles deposition had significantly decreased the frictional forces between brackets and stainless steel wires.

Samorodnitzky et al.[27] found a significant decrease in kinetic and static frictional forces in NiTi and stainless steel orthodontic wires coated with inorganic fullerene of tungsten disulfide (IF-WS2) nanoparticles embedded in Co matrix up to 66%. They concluded that low friction nanocoatings could be applied for other biomedical purposes, as cardiovascular and orthopedic treatments. Wei et al.[28] coated stainless steel orthodontic wires with CNx film and observed a significant reduction in the wire-bracket friction both in artificial saliva and in air.

Rapoport et al.[29] and Cizaire et al.[30] demonstrated the mechanism by which the frictional forces decrease between the wire and bracket after nanoparticles deposition. At first, nanoparticles act as a spacer, when the wire and bracket slots are parallel to each other, decreasing the surface sharpness and frictional forces. The frictional forces increased at slot edges, between the wire and the bracket slot angle. At that phase, some of the deposited particles flakes off the wires and their path of motion become more lubricious. The deposited nanoparticles are slowly flaked and washed out at interfacial areas under force application. It could also be stated that the deposition of ZnO nanoparticles on orthodontic wires can decrease frictional forces because nanoparticles protect the metallic wires against oxidation.[31]

Limitations of the study can be related to the fact that the exact coating thickness was not detected and also the variability of coating thickness with electrochemical deposition time, solution concentration and composition were not measured.

CONCLUSIONS

A unique coating on NiTi substrate was obtained using ZnO nanoparticles, which may have superior anti-bacterial effect against Gram-negative and Gram-positive bacteria and superior frictional performance. Nanoparticles coatings can be used in future orthodontic treatments.

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Effect of surface treatments on the adhesive properties of metallic brackets on fluorotic enamel

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Objective: To compare the effectiveness of the pretreatment with sandblasting and deproteinization with NaOCl on bond strength (SBS), *in situ* conversion degree (CD) of brackets in fluorotic enamel, and enamel etching pattern.

Methods: A total of 90 non-carious maxillary premolars were used. The teeth were then assigned to six experimental groups according to: enamel surface (sound and fluorotic enamel); surface treatment (Regular etch with 37% phosphoric acid [RE]; 5.2% sodium hypochlorite + phosphoric acid [NaOCl + RE]; sandblasting + phosphoric acid [sandblasting + RE]). After storage in distilled water (37°C/24h), the specimens were tested at 1 mm/min until failure (SBS). Enamel–resin cement interfaces were evaluated for CD using micro-Raman spectroscopy. The enamel-etching pattern was evaluated under a scanning electron microscope. Data from SBS and *in situ* CD values were analyzed using ANOVA two-away and Tukey test (α=0.05). The enamel etching pattern was evaluated only qualitatively.

Results: For sound enamel, RE showed the highest SBS values, when compared to NaOCl + RE and Sandblasting + RE groups ($p < 0.01$). Regarding CD, only NaOCl + RE significantly compromised the mean DC, in comparison with other groups ($p = 0.002$). For fluorotic enamel, the Sandblasting + RE group significantly increased the mean SBS values, in comparison with RE group ($p = 0.01$) and no significant change was observed for CD ($p > 0.52$).

Conclusions: The application of NaOCl or sandblasting associated to phosphoric acid improved the SBS of the brackets in fluorotic enamel without compromising the CD of the resin cement, with improving of enamel interprismatic conditioning.

Keyword: Orthodontics. Sodium hypochlorite. Dental fluorosis. Conversion degree.

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INTRODUCTION

The success of the orthodontic treatment using fixed appliances depends substantially on the enamel-brackets bonding.[1] Unfortunately, bracket bonding failure during the course of orthodontic treatment is a common complication in daily practice,[2] and it is associated with emergency appointments, thus prolonging treatment time and promoting discomfort to the patients.

Although bracket bonding failure can occur in sound enamel, a worse adhesion is expected when bonding to fluorotic enamel. Fluorotic enamel is more porous and hypomineralized, with often smaller crystallites.[3,4] Additionally, it has been reported that the mineralized surface layer contains hydrohyapatite, fluoridated-hydroxyapatite and fluorapatite crystals more acid resistant,[5] which a significantly higher protein content as compared to normal enamel,[3] compromising the adequate enamel-bracket bonding.

Thus, alternative treatments to increase the bracket retention in fluorotic teeth are suggested.[6] One of them is to increase enamel surface roughness applying an intraoral sandblasting[7] with aluminum oxide particles propelled by air pressure, promoting microscopic conditioning.[8,9] Other alternative is to apply a deproteinization agent, due to higher amount of organic matrix in fluorotic enamel.[3] Sodium hypochlorite (NaOCl) solution removes the excess of protein content[10] and may be a possible strategy to optimize adhesion by removing organic elements of the enamel structure and the biofilm.[11]

Moreover, the conversion of monomer into polymer plays an important role in successful enamel-brackets bonding.[12,13] The conversion degree of orthodontics resin cement was previously reported; however, the authors[12] did not evaluate the conversion degree into the adhesive interface especially after sandblasting or deproteinization treatment in fluorotic enamel.

Additionally, both alternatives (sandblasting or deproteinization agent) were not compared in the same study[6,14,15] in fluorotic enamel. Thus, the aim of the present study was to compare the effectiveness of pretreatment using deproteinization with NaOCl or sandblasting on shear bond strength; *in situ* conversion degree of brackets in fluorotic enamel, and enamel etching pattern were also compared

MATERIAL AND METHODS

Tooth selection and specimen preparation

Diagnosis of dental fluorosis was made according to the severity using the Thylstrup and Fejerskov index (TFI).[16] Previously to selection of teeth, two examiners were submitted to training and calibration procedure according to Ermis et al.[17] A total of 90 non-carious human maxillary premolars were used. Forty-five fluorosed teeth with TFI score of 4 and forty-five with TFI of 0 (without fluorosis), were obtained. The teeth were collected after obtaining the patients' informed consent under a protocol approved by the Ethics Committee Review Board of the *Universidade Estadual de Ponta Grossa* (2.522.293). The teeth were disinfected in 0.5% chloramine, stored in distilled water, and used within six months of extraction.

Experimental design and sample size calculation

Ninety teeth (45 TFI = 0 and 45 TFI = 4) were then assigned to six experimental groups (n = 15 per group; 10 to shear bond strength; 4 to *in situ* conversion degree, and 1 to enamel etching pattern) according to the combination of the independent variables: enamel surface (sound or fluorotic enamel); surface treatment (regular etch with 37% phosphoric acid [RE]; 5.2% sodium hypoclorite [Fórmula & Ação, São Paulo/SP, Brazil] + phosphoric acid [NaOCl + RE]; and sandblasting [RONDOflex Plus, Kavo Kerr, Joinville/SC, Brazil] + phosphoric acid [Sandblasting + RE]).

For establishing the sample size, the bond strength values of metallic brackets to fluorotic enamel were considered. According to previous literature, mean and standard deviation of metallic brackets to fluorotic enamel was 11.0 ± 3.1.[6,14,18] Using an α of 0.05, a power of 90% and a two-sided test, the minimal sample size was 10 teeth in each group in order to detect a difference of 5 MPa among the tested groups.

Bonding procedures

For shear bond strength (SBS) test, the roots of the 60 teeth were centrally embedded in a polyvinyl chloride tube (10 mm high x 13 mm diameter) using a chemically cured acrylic resin (Jet Clássico, São Paulo/SP, Brazil) until two-thirds of the root, with the labial surfaces parallel to the mold base so that they would be parallel to the force during the bond test. The buccal surface of each tooth was positioned perpendicularly to the base and the buccal surfaces of the teeth were cleaned and polished with oil- and fluoride-free fine pumice using a slow-speed handpiece, then rinsed with water and dried.

All step-by-step bonding procedures are described in Table 1 according to the respective groups. For all groups, the bracket bonding was made with Orthocem resin cement (FGM Dental Products, Joinville/SC, Brazil), according to the experimental groups (Table 1). After the surface pretreatment, the enamel surface was etched with 37% phosphoric acid (Condac 37, FGM Dental Products, Joinville/SC, Brazil) for 30 s, rinsing for 15 s and air-dry for 30 s. A small amount of the bonding resin was applied to the bracket (BioQuick®, Forestadent®, Pforzheim, Germany) and positioned on the flat surface and pressed. The excess of the resin cement was removed with a sharp explorer and light-curing was performed using a LED light-curing unit set at 1000 mW/cm^2(Valo, Ultradent Products Inc, South Jordan, UT, USA). A radiometer (Demetron L.E.D. radiometer, Kerr, Victoria, Australia) was used to check the light intensity every five specimens.

Shear bond strength testing

After storage in distilled water for 24 hours at 37°C, the specimens were attached to a shear-testing device (Odeme Biotechnology, Joaçaba/SC, Brazil) and tested in a universal testing machine (Kratos IKCL 3-USB, Kratos Equipamentos Industriais Ltda, Cotia/SP, Brazil) with a 500-N load cell. Each specimen was positioned in the universal testing machine and a chisel tip was placed onto the bracket-enamel interface. The setup was maintained in

Table 1 - Resin cement (batch number), composition, groups, and application mode.

Resin cement (batch number)	Composition	Groups	Application mode (*)
Orthocem FGM Dental Products (# 141217)	Resin cement: BisGMA, TEGDMA, methacrylic phosphatized monomers, stabilizer, CQ, co-initiators, silicon dioxide nanometric loading.	Sound and fluorotic enamel (RE)	1. Apply 37% phosphoric acid (Condac 37) for 30 s 2. Rinse for 30 s and air-dry 3. Apply small amount of resin cement onto the base of the bracket and set it on position 4. Remove the excess 5. Light-cure for 20 s at 1200 mW/cm^2 for each margin.
		Sound and fluorotic enamel + NaOCl 5.2% (NaOCl + RE)	1. Actively apply 5.2% NaOCl for 1 min 2. Apply 37% phosphoric acid (Condac 37) for 30 s 3. Rinse for 30 s and air-dry 4. Apply small amount of resin cement onto the base of the bracket and set it on position 5. Remove the excess 6. Light-cure for 20 s at 1200 mW/cm^2 for each margin.
		Sound enamel and fluorotic enamel + sandblasting (Sandblasting + RE)	1. Sandblasting with 27-μm aluminum oxide at 80 psi for 20 s at 5 mm from labial surface at a 90° angle. 2. Apply 37% phosphoric acid (Condac 37) for 30 s 3. Rinse for 30 s and air-dry 4. Apply small amount of resin cement onto the base of the bracket and set it on position 5. Remove the excess 6. Light-cure for 20 s at 1200 mW/cm^2 for each margin.

*The materials were applied according to the recommendations of their respective manufacturers.
Bis-GMA = bisphenolglycidyl methacrylate; TEGDMA = triethylenelglycidyl methacrylate; CQ = camphorquinone.

alignment (resin cement–enamel interface, the chisel, and the center of the load cell) to ensure the correct orientation of the shear forces. The crosshead speed in the compressive mode was set at 1 mm/min until failure.

The SBS values (MPa) were calculated by dividing the load at failure by the surface area (mm^2). After testing, the specimens were examined in an optical microscope (SZH-131, Olympus Ltd, Tokyo, Japan) at 10x magnification, to define the adhesive remnant index (ARI) adhered to the tooth and bracket after bracket debonding.[19] All teeth were analyzed by the same evaluator. The ARI modified was used to classify the failure modes: score 0 = no resin cement left on the tooth; score 1 = less than half of resin cement left on the tooth; score 2 = more than half of resin cement left on the tooth; score 3 = all resin cement left on the tooth with distinct impression of the bracket base. [19]

In situ conversion degree (CD)

Twelve sound enamel teeth and twelve fluorotic enamel teeth were used in this topic. The roots of the teeth were removed by sectioning at the cementoenamel junction. The enamel surface was treated and resin cement build-ups were constructed on the bonded enamel using the same protocols described for the SBS test. After storage of the restored teeth in distilled water at 37°C for 24 hours, the resin cement–enamel specimens were longitudinally sectioned across the bonded interface with a low-speed diamond saw (Isomet, Buehler Ltd, Lake Bluff, IL, USA) to obtain two resin–enamel slices.

The resin cement–enamel slices were wet polished with 1500-, 2000- and 2500-grit SiC paper for 15 seconds each. Then they were ultrasonically cleaned for 20 minutes in distilled water and stored in water for 24 hours at 37°C. The micro-Raman equipment (XploRA ONE™ Raman microscope, HORIBA Scientific, New Jersey, NY, USA) was first calibrated for zero and then for coefficient values using a silicon sample. The samples were analyzed using a 638-nm diode laser through an x100/0.9 NA air objective. The Raman signal was acquired using a 600-lines/mm grafting centered between 600 and 1800 cm^{-1}, and the employed parameters were 100 mW, spatial resolution of 3 µm, spectral resolution of 5 cm^{-1}, accumulation time of 30 s, with 5 co-additions.

Spectra were taken at the resin cement-enamel adhesive interface at three dissolver sites for each specimen. Spectra of uncured resin cement were taken as references. The ratio of double-bond content of monomer to polymer in the adhesive was calculated according to the following formula: DC (%) = (1- [R cured / R uncured]) × 100, where R is the ratio of aliphatic and aromatic peak intensities at 1639 cm^{-1} and 1609 cm^{-1} in cured and uncured resin cement.

Enamel etching pattern

The enamel-etching pattern was qualitative evaluated on the enamel surface under scanning electron microscope (MIRA TESCAN, Shimadzu, Tokyo, Japan). For this purpose, sound enamel teeth (n = 3) and fluorotic enamel teeth (n = 3) were sectioned in the diagonals across the long axis of the tooth with a water-cooled low-speed diamond saw (Isomet 1000) in order to obtain four enamel specimens.[20] The enamel specimens were conditioned according to the following groups:

1. Regular etch with 37% phosphoric acid (RE);
2. NaOCl + phosphoric acid (NaOCl + RE);
3. Sandblasting + phosphoric acid (Sandblasting + RE).

The surfaces were then rinsed off with tap water for 30 s and air dried with an air spray for 5 s. All specimens were dried and dehydrated in a desiccator for 12 hours, and the conditioned enamel surfaces were sputter coated with gold/palladium in a vacuum evaporator (SCD 050, Balzers, Schaan, Liechtenstein). The entire surface of treated enamel was examined under a scanning electron microscope (MIRA TESCAN, Shimadzu, Tokyo, Japan). Photomicrographs of representative surface areas were taken at 5000x magnification.

Statistical analysis

After evaluation of the normality by the Shapiro-Wilk test and homoscedasticity of the variances by the Bartlett test (not shown data), data from SBS and *in situ* CD values were analyzed using two-way ANOVA (enamel surface *vs* surface treatment) and Tukey *post-hoc* test at a level of significance of 5%. The enamel etching pattern was evaluated only qualitatively.

RESULTS

Shear bond strength testing

The ARI of all groups showed a higher variability between failures scores (Table 2). The RE group showed higher presence of scores 2 and 3 (90%) in sound enamel. On the other side, in fluorotic enamel, 90% of the failures were scored as 0 or 1. In sound enamel, the failure pattern to deproteinization (NaOCl + RE) showed scores 1 and 2 (50% each one) for sound enamel, and scores 1 and 3 for fluorotic enamel. When Sandblasting + RE group was evaluated, the failure pattern was 90% scores 0 for sound enamel and 90% scores 2 and 3 for fluorotic enamel.

Regarding to two-way ANOVA test of SBS values, the cross-product interaction enamel surface *vs* surface treatment was statistically significant ($p = 0.01$, Table 3). The application of RE group in sound enamel showed the highest and statistically significant SBS value, when compared to all groups ($p = 0.01$, Table 3). For sound enamel, both alternative treatment (NaOCl + RE and Sandblasting + RE) significant decrease the SBS values ($p = 0.01$, Table 3). For fluorotic enamel, the application of NaOCl + RE, as well as Sandblasting + RE, increased the SBS values, but only significantly when Sandblasting + RE was compared with ER group ($p = 0.01$, Table 3).

In situ conversion degree (CD)

Regarding to two-way ANOVA test of CD values, the cross-product interaction enamel surface *vs* surface treatment was statistically significant ($p = 0.002$, Table 4). The application of RE in sound enamel showed higher and statistically similar CD value when compared to Sandblasting + RE ($p = 0.32$, Table 4). For sound enamel, the application of NaOCl + RE significantly decreased the CD values ($p = 0.002$, Table 4). For fluorotic enamel, the application of NaOCl + RE or Sandblasting + RE did not significantly change the CD, in comparison with RE group ($p > 0.52$, Table 4).

Table 2 - Percentage of Adhesive Remnant Index (ARI) according to the each score of the different experimental groups

Groups	Sound enamel (ARI)				Fluorotic enamel (ARI)			
	0	1	2	3	0	1	2	3
RE	--	10	40	50	80	20	--	--
NaOCl + ER	--	50	50	--	--	20	30	50
Sandblasting + RE	90	10	--	--	--	10	40	50

(*) ARI scores: score 0 = no resin cement left on the tooth; score 1 = less than half of resin cement left on the tooth; score 2 = more than half of resin cement left on the tooth; score 3 = all resin cement left on the tooth, with distinct impression of the bracket base.

Table 3 - Mean and standard deviations of the shear bond strength (MPa) values of the different experimental groups

	Sound enamel	Fluorotic enamel
RE	17.3 ± 2.1^{a}	9.7 ± 2.1^{c}
NaOCl + ER	11.8 ± 3.2^{b}	$11.7 \pm 2.8^{b,c}$
Sandblasting + RE	12.2 ± 2.7^{b}	12.7 ± 2.1^{b}

(*) Different letters indicate means statistically different (Two-way ANOVA and Tukey test; $p = 0.01$).

Table 4 - Mean and standard deviations of the *in situ* conversion degree (%) values of the different experimental groups

	Sound enamel	Fluorotic enamel
RE	70.3 ± 2.8^{a}	58.0 ± 2.0^{b}
NaOCl + ER	61.2 ± 1.7^{b}	57.1 ± 1.9^{b}
Sandblasting + RE	68.6 ± 2.1^{a}	57.3 ± 2.4^{b}

(*) Different letters indicate means statistically different (Two-way ANOVA and Tukey test; $p = 0.002$).

Enamel etching pattern

After qualitative evaluation in sound enamel, the RE promoted a deepest and most organized etching pattern, with a presence of the prism core and an intact prism periphery. After NaOCl + RE treatment, a higher dissolution of the mineral content and prism periphery was observed. After Sandblasting + RE, an increase of the surface modification and dissolution on the prism core, with a significant destruction structural of the aprismatic area, was found, when compared with other groups (Fig 1).

According to qualitative evaluation of fluorotic enamel, an increase of the micro-irregularity and porosity was observed independently of the treatment. NaOCl + RE and Sandblasting + RE groups increased the dissolution of prism core with improving of interprismatic conditioning (Fig 1). When Sandblasting + RE was applied, the prism peripheries have been partially removed, becoming more pronounced, leaving the prism cores relatively intact (Fig 1).

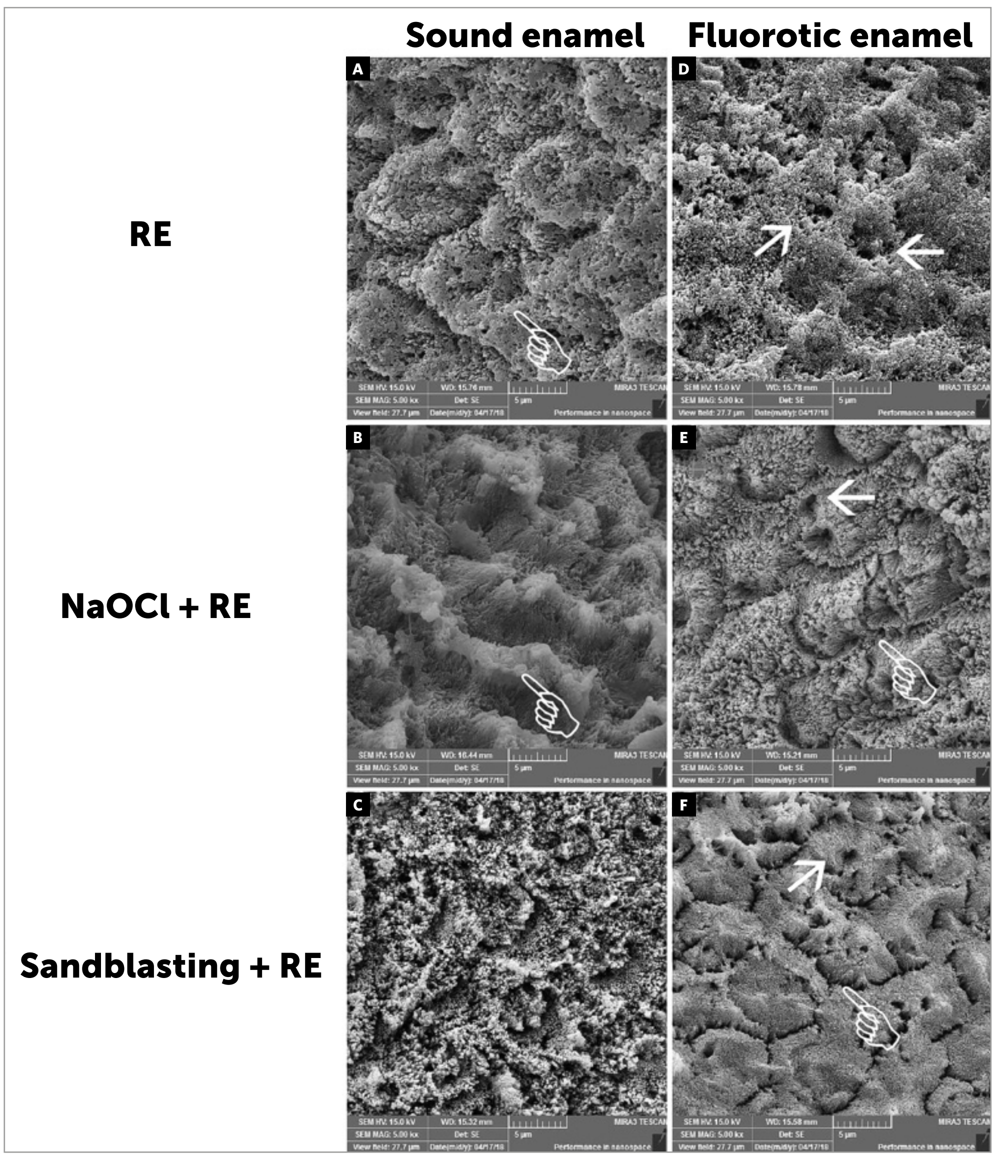

Figure 1 - Representative morphology of sound (**A, B, C**) and fluorotic enamel (**D, E, F**) after different treatment. RE resulted in a best-defined etching pattern (white hand, in **A**). NaOCl significantly changed the quality of the etching pattern and prism periphery (white hands, in **B**). Sandblasting promoted a significant structural destruction, with total prism core dissolution (**C**). Fluorotic enamel showed an increase of the porous number (white arrows in **D** to **F**). Better signs of the interprismatic conditioning were observed after treatment in fluorotic enamel (white hands, in **E** and **F**). Prism peripheries have been only partially removed (white hand, in **F**), becoming more pronounced, leaving the prism cores relatively intact (white arrow, in **F**).

DISCUSSION

The results of the present study showed that the application of only phosphoric acid showed the highest bond strength to sound enamel, when compared to fluorotic enamel. It is known that structural differences between normal and fluorotic enamel teeth can influence the bond strength.[17,21] Dental fluorosis is characterized by a hypermineralized layer, with the presence of fluorapatite in the outer enamel surface more crystalline and stable, making it resists dissolution in acid-etchant.[3] Thus, these morphological alterations could have promoted the reduction of the bond strength to fluorotic enamel. Additionally, a higher number of ARI scores 0 and 1 was observed in fluorotic enamel, showing the lower interaction with the fluorotic enamel surface in general. On the other side, in the sound enamel, more than 90% were ARI scores 2 and 3, showing intense interaction with surface of sound enamel. It is known that a direct correlation between higher ARI score and higher bond strength is expected.[22]

Some reports have suggested that the application of NaOCl before etching eliminates the organic substances from the enamel surface, and this may increase the bond strength to enamel because it results in an increase in the total conditioning area.[11,23] On the other hand, several studies have shown that de deproteinization with NaOCl decreased the bond strength of metallic bracket due to incapacity of improving the quality of the decalcification pattern.[24,25] The results of the present study are in accordance to Trindade et al,[24] in which the application of NaOCl significantly decreased the bond strength to sound enamel. Additionally, it is known that NaOCl forms reactive free radicals and can inhibit the adequate polymerization.[26,27] These reactive residual free radicals compete with the propagating vinyl free radicals generated during light activation, resulting in premature chain termination and incomplete polymerization.[26] Thus, the authors of the present study also speculates that the presence of these residual radicals on the sound enamel decreases the conversion degree inside the enamel-resin cement interface and consequently promotes a reduction of the bond strength values.

However, when NaOCl was applied on fluorotic enamel, an increase in the bond strength values was observed. It is known that fluorotic enamel contains significantly higher protein content.[3] Thus, it can be hypothesized that the sodium hypochlorite reacted with the higher protein content present on the fluorotic enamel, [3] generating less reactive residual free radicals to inhibit the adequate polymerization without compromising the conversion degree. Unfortunately, these results cannot be compared with previously literature, mainly because, to the extent of author's knowledge, this is the first study that evaluated the *in situ* conversion degree inside the enamel-resin cement-bracket interface. Therefore, future studies are needed to prove this hypothesis.

Regarding the use of sandblasting, controversial results for bond strength values were observed in the literature when sound and fluorotic teeth where compared.[9,14,18,28-30] It has been suggested that sandblasting of enamel in association with phosphoric acid removes oxides and contaminants from teeth surface, increasing the total energy surface and roughness.[9] This effect could be partially showed when observing the microscopy evaluation for sound and fluorotic enamel. It could be seen a significant increase of the roughness and porosity existing in both enamel substrates after sandblasting and phosphoric acid, when compared with only phosphoric acid.

However, for sound enamel, the sandblasting decreased the bond strength values when compared to RE group. On the other hand, in fluorotic enamel, a significant increase in the bond strength values occurred when sandblasting was applied. These different results are also showed in the evaluation of the ARI score. A higher number of scores 2 and 3 (90%) for sandblasting + RE occurred in the fluorotic enamel, meaning that at least more than half of resin cement was left on the fluorotic enamel surface. However, when the sandblasting + RE was applied in the sound enamel, the ARI scores were predominantly 0 and 1, meaning lower interaction with the sound enamel surface.

Based on these findings, it is inferred that a good interaction between sound enamel and resin cement used after sandblasting application in sound enamel does not occur. It is unclear for the authors of the present study what is the reason for the decrease on bond strength values in sound enamel. However, although exists a common sense that sandblasting has a positive effect in the sound enamel, a recently published systematic review and meta-analysis of *in vitro* studies showed that the sandblasting did not increase the bond strength values of orthodontic brackets.[9] However, the extrapolation of these findings is limited because the conclusion was only supported by two *in vitro* studies.[9] The lack of standardizing in methodological approaches for different studies could be the reason for the lower number of *in vitro* studies evaluated in the Baumgartner' study.[9] Therefore, future better designs and controlled *in vitro* studies are needed to evaluate the effect of these variables in sound enamel.

Surprising, in fluorotic enamel a significant increase in the bond strength values when sandblasting was applied occurred. These findings are also controversial.[14,28] As fluorotic enamel is less reactive than sound enamel, it is reasonable to speculate that the microporosities of the fluorotic enamel surface after the application of sandblasting is improved, thus increasing the bonding area[14,31] and, consequently, producing a significant increase of the bond strength values,[14,28] when compared to only phosphoric acid applied in fluorotic enamel.

It is important to mention the possible limitations in the present study. The results of the present study are based on the immediate results, without any aging method. Commonly, thermocycling is the common method used to evaluate bond durability[32-34] and simulate the thermal changes that occur in the oral environment.[34] However, the varied number of cycles, the choice of temperature, time conditions, and intervals between baths hinder comparison of the results.[6,13,34] Therefore, further studies should be conducted to investigate if the NaOCl and sandblasting can preserve the resin cement–fluorotic enamel interface from degradation in longer periods of time.

Thus, the results of the present study suggest that the alternative surface treatment evaluated (NaOCl or sandblasting) improve the bond strength on fluorotic enamel without compromising the conversion degree of the resin cement used.

CONCLUSIONS

The application of NaOCl or sandblasting associated with phosphoric acid improved the bonding of the metallic brackets in fluorotic enamel without compromising the *in situ* conversion degree of the resin cement. The treatment compromise the bond strength to sound enamel.

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The ability of orthodontists and maxillofacial surgeons in predicting spontaneous eruption of mandibular third molar using panoramic serial radiographs

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Objective: To evaluate the skill of orthodontists and oral/maxillofacial surgeons (OMFS) in providing a prognosis of mandibular third molars spontaneously erupted, through follow-up panoramic analysis.

Methods: 22 orthodontic patients treated without extraction, presenting spontaneously erupted mandibular third molars (n = 44) were analyzed through panoramic serial radiographs. The first panoramic radiograph was obtained just after orthodontic treatment (PR1), in patients aging from 13 to 19 years. A second panoramic radiograph (PR2), was obtained in average two years later. The radiographs were randomly analyzed by 54 specialists, 27 orthodontists and 27 OMFS, to obtain the opinion about the approach to be adopted to these teeth in PR1. Then, another opinion was collected by adding a serial radiograph (PR1+2).

Results: The concordance of the answers was moderate for OMFS (Kappa 0.44; $p < 0.0001$) and significant for orthodontists (Kappa 0.39; $p < 0.0001$). In the analysis of the first radiograph (PR1) of the spontaneously erupted molars, OMFS indicated extraction in 44.5% of cases, while orthodontists indicated in 42%, with no difference between groups ($p = 0.22$). In PR1+2 analysis, orthodontists maintained the same level of extraction indication (45.6%, $p = 0.08$), while surgeons indicated more extractions (63.2%, $p < 0.0001$).

Conclusions: Orthodontists and OMFS were not able to predict the eruption of the third molars that have erupted spontaneously. Both indicated extractions around half of the third molars. A follow-up analysis, including one more radiograph, did not improve the accuracy of prognosis among orthodontists and worsened for OMFS.

Keywords: Third molar. Tooth extraction. Orthodontist. Oral and maxillofacial surgeon.

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

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INTRODUCTION

Third molars are the most often impacted teeth,[1-4] with a prevalence ranging from 9.5% to 39% among various populations[5]. Moreover, 75% of people receiving regular dental treatment have the third molars removed[6]. Lack of retromolar space,[7-10] deficient mandibular growth[9], distal eruption of dentition,[7] condylar vertical growth direction,[9] increased size of the crown,[7] and late maturing[11] have been reported as the most common causes of impaction.

The decision to preserve or remove third molars remains unclear to the clinician, partly because of the imprecision of prediction models on impacted molars reported in the literature.[12-17] Thus, this decision seems to be centered on the preference of each speciality[18], rather than a clinical approach based on scientific evidence. With so many controversies, prophylactic removal of third molars has been adopted under the assumption of preventing future damage,[19] such as pericoronitis,[2] osteitis, osteomyelitis,[20] dentigerous cysts,[21] caries in the distal of the second molar[22], or root resorption in neighboring teeth.[23] Furthermore, the tertiary crowding in adults[24-26] and the risk of relapse after orthodontic treatment[26] have been associated to the presence of third molars, although most studies have demonstrated that third molars have a negligible influence on the long-term changes occurring in the mandibular arch.[27,28]

On the other hand, some risks and complications[29] may be associated with surgical removal of third molars, including alveolitis, injury to the inferior alveolar nerve,[30] infections,[31] and mandibular fracture.[32] The most conservative approach is to carefully monitor asymptomatic third molars.[33] This approach is based mainly in the absence of scientific evidence to justify prophylactic extraction.[17] Monitoring should be performed every two years up to at least the age of 18.[8]

In order to examine the ability of experts on predicting the possibility of eruption of mandibular third molars (M3M), a study showed that orthodontists and oral/maxillofacial surgeons (OMFS) were unable to predict the prognosis of spontaneously erupted M3M after examining a single panoramic radiograph in 38.8% and 49.6% of the cases, respectively.[17] The serial analysis of panoramic radiographs,[8] a method widely used for clinical monitoring of orthodontic patients, might be able to increase the accuracy of this prediction. In this sense, the objective of this study is to evaluate the skills of orthodontists and OMFS in providing a prognosis for spontaneously erupted M3M by longitudinal monitoring through panoramic radiographs.

METHODS

This study was approved by the Human Research Ethics Committee of the Institute of Health Sciences of the Federal University of Pará (CEP-ICS/UFPA, protocol # 498024). Each dentist participating signed an Informed Consent Form. In addition, a Use of Database Agreement was signed by the orthodontist who provided patient clinical records and radiographs.

The sample included 22 patients, whose panoramic radiographs, two for each patient (n=44), were obtained from clinical records belonging to a single orthodontist in private practice. They were selected retrospectively from patients who had completed orthodontic treatment without extractions, and whose third molars had spontaneously erupted and were clinically asymptomatic. All patients had at least two panoramic radiographs: the first taken at the end of the orthodontic treatment (PR1, Fig 1A). A second image (PR2, Fig 1B) was obtained around two years after treatment, with the aim of monitoring the eruption of the mandibular third molars. Patients with agenesis, tooth loss, or extraction for orthodontic needs were previously excluded.

Twelve men and 10 women, with a mean age of 14.5 years in the PR1 (13-16.6 years), and 16.8 years in the PR2 (15.5-19.6 years) were evaluated. A male patient, 15.4 years old in PR1 and 16.9 years in the PR2 (Figs 2A and 2B), whose third molars were severely impacted at 21.2 years (Fig 2C), was selected as a negative control. The inclusion of this case was carried out by a pilot study, in which five orthodontists unanimously indicated the impaction of the teeth on radiographs when the patient was 21.2 years.

Images of each radiograph was obtained using a digital camera (Canon EOS Digital Rebel EF-S 18-55; Canon Inc., Tokyo, Japan). The images were cropped in order to highlight the region of the mandibular third molars, ramus and angle of the mandible (Figs 1A and 1B). Radiographs were assembled

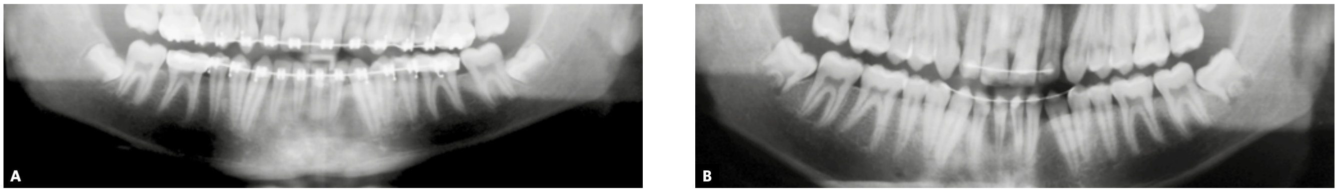

Figure 1 - Panoramic radiograph after orthodontic treatment of the patient #6 at: A) 14 years and 9 months of age (PR1) and B) 16 years and 7 months (PR2). When examining the PR1, 64.7% of orthodontists and 29.4% of OMFS indicated the extraction of left M3M, while 64.7% of orthodontists and 35.3% of OMFS indicated the extraction of right M3M. By examining the two radiographs (PR1+2), 23.5% of orthodontists and 76.4% of OMFS indicated the extraction of the left M3M, while 17.6% of orthodontists and 70.6% of OMFS indicated extraction of the right M3M.

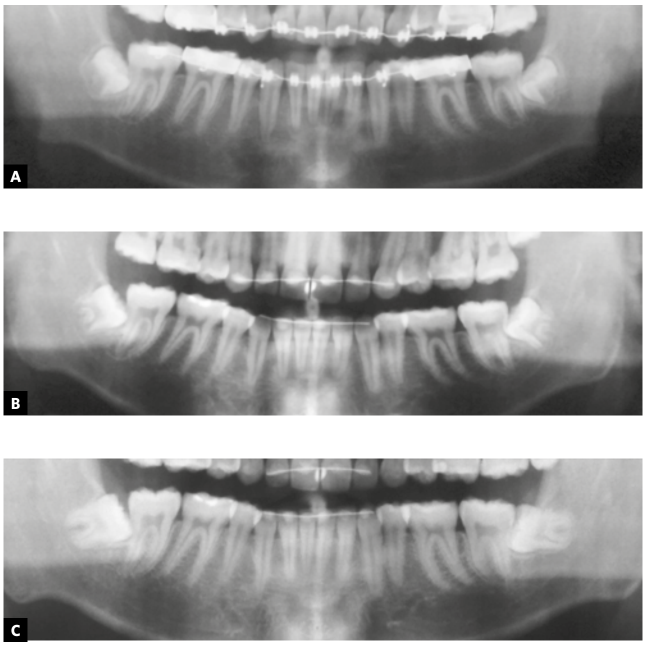

Figure 2 - Panoramic radiograph at: A) the end of orthodontic treatment (PR1) and B) follow-up (PR2), of the patient used as a negative control case. Confirmation of the impaction was defined by a third radiograph (C), at 21.3 years.

randomly in a PowerPoint presentation (Microsoft, Redmond, USA). In addition, the age and sex of each patient were provided.

Fifty-four experts, 27 orthodontists and 27 OMFS, enrolled in the Regional Council of Dentistry of Pará (Brazil) were invited to provide a prognosis for the 44 mandibular third molars. The number of professionals enrolled in this study was based on a previous study[18], which was shown to have enough power to detect intergroup differences. Three dentists declined to participate in the study (two orthodontists and one OMFS).

The experts first evaluated the panoramic radiographs at the end of orthodontic treatment (PR1) and were requested to indicate a prognosis for M3M bilaterally. The options included: monitoring, extraction, or other. Then, the experts examined the two radiographs together (PR1+2) at random, and indicated the prognosis again.

In cases where professionals adopted "extraction" as the preferred treatment for the tooth, they were asked to justify their decision with one of the following six options: 1) the presence or potential to develop a pathology; 2) second molar resorption risk; 3) it may lead to crowding; 4) caries risk; 5) tooth impacted or at risk of impaction; 6) other.

These analyses were performed for all 44 M3M that had spontaneously erupted and the negative control, totaling 46 M3M in 23 patients examined through 46 radiographs. Respondents were given sufficient time to respond to the questionnaire.

To evaluate the method error, images of two patients (#13 and #15), including four M3M, were duplicated and were reassessed by each of the 54 examiners. The Kappa test was used to examine agreement of the intraexaminer and interexaminers responses. The intragroup and intergroups differences were evaluated by the chi-square test. Data were subjected to statistical analysis, with a significance level of 5%, using BioEstat 5.3 software (Mamirauá Institute, Belém/Pará, Brazil).

RESULTS

The analysis of the cases duplicated, corresponding to four M3M, revealed a moderate agreement[34] among the orthodontists (Kappa = 0.46) and OMFS (Kappa = 0.47) when the PR1 (Table 1) was evaluated. In the following analysis, in which a second radiograph was evaluated together with the first (PR1+2), the agreement increased significantly between orthodontists (Kappa = 0.65) and OMFS (Kappa = 0.67).

Table 1 - Concordance of the answers related to the conduct adopted by oral/maxillofacial surgeons (OMFS) and orthodontists (ORTHO) compared to the third molars in the replicated cases (n=4) when examined the first panoramic radiograph (PR1) or two serial radiographs (PR1+2).

	PR1				PR1+2			
	ORTHO		OMFS		ORTHO		OMFS	
	RCC	Extraction	RCC	Extraction	RCC	Extraction	RCC	Extraction
RCC	72	10	53	11	62	11	37	9
Extraction	11	15	16	28	6	29	8	54
Kappa	0.46		0.47		0.65		0.67	
p-value	<0.0001		<0.0001		<0.0001		<0.0001	

RCC: radiographic clinical control.

Table 2 - Frequency agreement (Kappa), and difference (x^2) of the responses indicated by orthodontists (ORTHO) and oral/maxillofacial surgeons (OMFS) on the clinical conduct adopted for the M3M that have spontaneously erupted (n=44), when examined one (PR1) or two serial panoramic radiographs (PR1+2).

Prognosis	PR1		PR1+2		PR1 vs PR1+2			
	ORTHO (n=27)	OMFS (n=27)	ORTHO (n=27)	OMFS (n=27)	Concordance (Kappa)		PR1 vs PR1+2 (x^2)	
					ORTHO	OMFS	ORTHO	OMFS
RCC	689 (58.0%)	657 (55.3%)	646 (54.4%)	436 (36.7%)	0.44 $p < 0.0001$	0.39 $p < 0.0001$	$p = 0.08$	$p < 0.001$
Extraction	499 (42.0%)	529 (44.5%)	542 (45.6%)	751 (63.2%)				
Others	0	2 (0.2%)	0	1 (0.1%)				
Total	1188	1188	1188	1188				
x^2 ORTHO vs OMFS (*p*-value)	1.63 (*p*=0.22)		74.54 (*p*<0.0001)					

RCC: radiographic clinical control.

Table 3 - Frequency agreement (Kappa), difference (x^2) of the responses indicated by orthodontists (ORTHO) and oral/maxillofacial surgeons (OMFS) on the clinical conduct adopted for the impacted M3M (n=2) in the analysis of one (PR1) or two serial panoramic radiographs (PR1+2).

Prognosis	PR1 (n=2)		PR1+2 (n=2)		PR1 vs PR1+2			
	ORTHO (n= 27)	OMFS (n= 27)	ORTHO (n= 27)	OMFS (n= 27)	Concordance (Kappa)		PR1 vs PR1+2 (x^2)	
					ORTHO	OMFS	ORTHO	OMFS
RCC	11 (20.4%)	14 (25.9%)	9 (16.7%)	6 (11.1%)	0.38 *p*=0.002	0.52 *p*<0.0001	$p = 0.8$	$p = 0.08$
Extraction	43 (79.6%)	40 (74.1%)	45 (83.3%)	48 (88.9%)				
Others	0	0	0	0				
Total	54	54	54	54				
X^2 ORTHO x OMFS (*p*-value)	0.24 (*p*=0.81)		3.92 (*p*=0.08)					

RCC: radiographic clinical control.

Table 4 - Reasons for choosing M3M extractions when orthodontists (ORTHO) and maxillofacial surgeons (OMFS) examined one (PR1) or two serial panoramic radiographs (PR1+2).

JUSTIFICATIONS	PR1 (n=22)		PR1+2 (n=22)	
	ORTHO (n=27)	OMFS (n= 27)	ORTHO (n=27)	OMFS (n= 27)
1. Resorption	312 (45.5%)	190 (23.0%)	187 (24.3%)	253 (20.3%)
2. Impaction	255 (37.1%)	314 (38.0%)	402 (52.3%)	431 (34.6%)
3. Tooth decay	37 (5.4%)	108 (13.0%)	79 (10.3%)	261 (20.9%)
4. Pathology	53 (7.7%)	111 (13.42%)	73 (9.5%)	208 (16.7%)
5. Crowding	27 (4.0%)	56 (6.8%)	28 (3.6%)	36 (3.0%)
6. Others	2 (0.3%)	48 (5.80%)	0	57 (4.5%)
Total	686	827	769	1246

In the analysis of the first panoramic radiograph (PR1), the OMFS indicated extraction in 44.5% of cases, while orthodontists indicated extraction in 42%, with no difference between them ($p = 0.22$, Table 2). In PR1+2, orthodontists maintained a similar level of extractions, when compared to the PR1 analysis (45.6%, $p = 0.08$), while the OMFS indicated more extractions (63.2%, $p < 0.0001$, Table 2). The Kappa agreement for only one radiograph, compared to using both radiographs (PR1+2), where the M3M erupted spontaneously (Table 2), was moderate for orthodontists (Kappa = 0.44) and considerable for OMFS (Kappa = 0.39).

In examining the impacted M3M (Fig 2, Table 3), orthodontists indicated extraction in 79.6% of the responses when examining a single panoramic radiograph (PR1). For OMFS, extraction was pointed out on 74.1%, with no significant difference between the two groups of examiners ($p = 0.81$). When assessing PR1+2, 83.3% of orthodontists indicated extraction, while this option was indicated by 88.9% of the OMFS ($p = 0.08$). Compared to PR1, orthodontists and OMFS indicated, respectively, 3.7% ($p = 0.8$) and 14.8% ($p = 0.08$) more extraction when evaluating PR1+2 in cases of impaction. Kappa values for the agreement between PR1 and PR1+2 was 0.52 for OMFS and only 0.38 for orthodontists (Table 3).

In the PR1 analysis, the most prevalent justification for extraction among the orthodontists was *"risk of resorption of the second molar"* (45.5%), while for OMFS it was *"impacted tooth or at risk of impaction"* (38%). In PR1+2, both orthodontists and OMFS indicated *"impaction"* as their main justification (52.3% and 34.6%, respectively).

DISCUSSION

The pathway of the third molars eruption have been the aim of several studies,[5,10,14] but it has not yet been possible to develop a reliable predictive model.[12-17] The prevalence of third molar impaction ranges from 9.5% to 39% among various populations.[5] Third molars become more uprighted until 25 years of age, usually erupting between 18 and 24 years of age[6]. This fact is due to changes in the sagittal position, which has been found in posttreatment follow-up of orthodontic patients.

The present findings showed that when mandibular third molars erupt spontaneously, about 42% of orthodontists and 44.5% of OMFS indicated the extraction when evaluating a single panoramic radiograph taken at the end of orthodontic treatment (Table 2). However, when two serial radiographs from the same patient are examined, OMFS indicated significantly more extractions (63.2%, $p < 0.0001$), while orthodontists tended to maintain the same opinion. These data reveal that the longitudinal follow-up by analysis of serial panoramic radiographs did not improve the accuracy of prognosis among orthodontists, and worsened the prognosis for surgeons.

For one patient in which both M3M were clearly impacted in the long-term follow-up (Fig 2, Table 3), it was found that the majority of professionals (79.6% of orthodontists and 74.1% of OMFS) indicated the extraction of third molars after examining the first radiograph (PR1). By adding a second serial radiograph (PR1+2), orthodontists indicated the same amount of extractions (83.3%, $p=0.8$), while OMFS indicated extraction in nearly 89% of cases, an increase of 14.8% compared to PR1, although not significantly different ($p=0.08$). A larger sample size of impacted teeth could detect this tendency of change in the prognosis. However, this fact corroborates the results obtained in the analysis of cases in which third molars erupted spontaneously, where OMFS tended to indicate more extractions when two serial radiographs were evaluated (PR1+2), regardless of the final position of these teeth.

In summary, in cases of mandibular third molar impactions, the prediction ability of OMFS seems to improve slightly when a longitudinal series of two radiographs is presented. However, it is worsened when the third molars erupt spontaneously. Among the orthodontist, no difference was observed, and for cases of spontaneous eruption, a correct prognosis is similar to the probability of choice by chance (50%). Thus, it seems that OMFS indicate more surgical removal of third molars when analyzing radiographs in which these teeth are in a more advanced stage of development.

Furthermore, since OMFS make decisions for more extractions than orthodontists in PR1+2, a lower intergroup agreement coefficient was found, when compared to the PR1 analysis.

When assessing the radiograph obtained at the end of the orthodontic treatment (PR1), the main reason among orthodontists to indicate extraction was the possibility of resorption of the second molar

(45.5%) (Table 4). For OMFS, the main reason was the risk of impaction of third molars (38%). These findings may be associated with the pathway eruption of third molars with a mesial angulation.[35] This angulation could lead to a more intimate contact with the adjacent tooth, leading professionals to plan a prophylactic extraction of M3M in order to prevent future pathological processes.[2,21,23] Thus, despite the similar display of surgical removal between the orthodontists and OMFS, the reasons for the indication appear to be different.

With PR1+2 analysis, the reason reported by most respondents for the indication of extraction of M3M was the risk of impaction for both orthodontists (52.3%) and OMFS (34.6%, Table 4). It is likely that the advanced root development and the end of the retromolar space growth, widely reported factors of third molar impaction,[8,36] have contributed to the reasons for their choice.

As the average age of the subjects in the present study was 14.5 years in PR1 and 16.8 years in PR2, a more conservative strategy would be to follow third molar development and position, by clinical and radiographic evaluation, until adulthood[2]. Also, active monitoring at 24-month intervals is recommended to allow the disclosure of clinical progression of periodontal disease[37] and this was the time period evaluated in this study. In contrast, when these teeth are the cause of some painful symptoms, there is a general consensus for extraction.[38]

In asymptomatic cases, regular monitoring is required, making questionable the risks of maintaining the patient, taking into account the patient's general state of health and the potential risk of systemic involvement.[39] Whenever indicating extraction of third molars, dentists should have a justifiable reason, taking into account future treatment planning from an orthodontic, surgical, periodontal and/or prosthetic point of view.[40] At the same time, a cost/benefit analysis should be carried out to justify the prophylactic removal of third molars.

The analysis of replicability of the cases studied showed greater concordance of responses when the two serial radiographs were examined (PR1+2) for both groups of evaluators (Table 1). This result seems to suggest that the higher the stage of development of the third molar, the greater agreement will be observed. However, this fact does not ensure a more accurate prognosis, whereas among OMFS, the level of error in the prognosis increased when the two radiographs were examined concurrently, at least for spontaneously erupted teeth.

The evaluation of panoramic radiographs to suggest an accurate diagnosis was a limiting factor in this study. Although radiographs are currently used as the main instrument to observe and monitor third molars, this method does not replace clinical evaluation of the patient. Computed tomography (CT) is considered a more accurate technique to evaluate the involvement of anatomical structures, such as the mandibular canal, with the mandibular third molars. However, the ability of professionals to predict the eruption of these teeth using CT demonstrated that a three-dimensional image does not seem to change the prognosis established by specialists.[41]

The most important finding of this study is the information that clinical decision to extract M3M can be precipitated and often misguided when based on two-dimensional radiographic examinations. The results showed that even if the radiographs are taken longitudinally, the accuracy of prognosis is not increased. Furthermore, it seems to exist a need for prospective longitudinal studies evaluating the consequence of surgical removal of mandibular third molars, as well as for clinical and radiographic control.[38]

CONCLUSIONS

These results allow us to conclude that orthodontists and oral/maxillofacial surgeons are not able to predict the prognosis of erupted mandibular third molars by examining a single panoramic radiograph. Both indicate extractions in almost half of spontaneously erupted teeth. Furthermore, the addition of a serial radiograph did not improve the accuracy of prognosis among orthodontists and worsened the accuracy for surgeons. Thus, it is suggested that these experts should re-evaluate their clinical protocol as well as radiographic guides used to establish a reliable prognosis on the eruption of third molars.

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Treatment of adult patient with hyperdivergent retrognathic phenotype and anterior open bite: report of a case with non-surgical orthodontic approach

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Adult patients with anterior open bite and hyperdivergent retrognathic phenotype demand complex treatments, as premolar extractions, molar intrusion or orthognathic surgery. In the present clinical case, a young adult patient without significant growth, with Class I and anterior open bite, was treated with four premolar extractions. The therapeutic result shows good intercuspidation, good facial esthetic, good function balance, and stability in a two-year post-fixed treatment follow-up.

Keywords: Hyperdivergent retrognathic phenotype. Anterior open bite. Premolar extractions. Non-surgical orthodontic therapy.

INTRODUCTION

Patients presenting hyperdivergent retrognathic phenotype demand complex orthodontic treatments.[1,2] Etiologically, such phenotype mainly combines the vertical facial genotype with an inadequate mandibular posture.[1,3] Such patients present three mandatory morphologic-functional features: a) deficient ratio between posterior and anterior facial heights, provoking a long and convex facial profile;[4,5] b) deficient masticatory function, with weaker bite force when compared to normal and hypodivergent subjects[6-8], and c) narrower dental arches, especially the maxillary one, with tendency of posterior crossbite occurrence.

Oral breathing is another environmental factor involved in the development of facial hyperdivergence, which evidence of cause-effect has been presented in primates.[9] Facial hyperdivergence has been related to clinical scenarios as enlarged adenoids,[10-14] allergic rhinitis,[15,16] enlarged tonsils,[17] and obstructive sleep apnea.[18] Eating habits and consequently muscle strength are environmental factors also related to facial hyperdivergence.[19,20] In such subjects, it has been postulated that vertical dimensions and mandibular

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morphology are already established at 6 years of age.[21] The maxilla presents excessive dentoalveolar growth in the posterior region. Mandibular rami are shorter than in normal and hypodivergent subjects, gonial angles are greater, dentoalveolar growth is excessive in the posterior region as well, the mandibular symphysis is taller and thinner, anterior lower facial height is increased and the mandibular plane angle is steeper.[1] Such features are associated with clockwise true mandibular rotation, and lesser chin anterior projection.[1] Transversally, hyperdivergent subjects present narrower dental arches, especially the maxillary, when compared to normal and hypodivergent subjects.[22-24] True mandibular rotation is frequently camouflaged by mandibular remodeling, and only apparent rotation[25,26] is clinically detected by orthodontists.

Contrary to common sense, evidence that support the relationship between anterior open bite and this facial phenotype is weak, mainly because anterior open bite is clearly more dentoalveolar than skeletal.[27-29] However, anterior open bite is a common feature of these subjects, as can be noticed in the present case report.

Many therapeutic protocols have been presented for hyperdivergent retrognathic patients, for example: high-pull headgears,[30] dental extractions,[31-35] posterior bite-blocks and vertical-pull chincup,[36-38] and orthodontic-surgical approaches.[39] In the same direction, Buschang et al[40] showed consistent results pursuing molars intrusion. They described intrusion of upper molars and secondary intrusion (actual or relative) of lower molars, with the use of coil springs and miniscrew implants.[40]

CASE REPORT

The patient, a Caucasian woman aged 16 years and 7 months, presented in a private office for initial orthodontic consultation. Her chief complaint was related to the open bite. The patient reported absence of significant records in her medical history. She had never been orthodontically treated. Clinically, no caries or other dental/periodontal problem was detected, and she presented good oral hygiene. The patient presented convex soft tissue profile, Class I malocclusion, permanent dentition, significant anterior open bite, significant overjet, mamelons in the incisal edges of the maxillary and mandibular incisors, maxillary right central incisor presenting yellowish hue, and moderate dental crowding in both dental arches (Figs 1 and 2).

The skeletal cephalometric assessment showed Class II tendency (ANB = 4°) and hyperdivergent facial type (SN.GoGn = 41° and FMA = 33°), as shown in Table 1 and Figure 3. Cervical vertebrae maturation stage[41] was CS6, suggesting that her active growth was virtually completed. Her convex profile and hyperdivergent facial features called attention for possible overeruption of molars and detrimental backward (clockwise) mandibular rotation.

The patient showed Class I malocclusion; significant overjet (6 mm); anterior open bite (3 mm); permanent dentition with full formed roots and all teeth completely erupted (except third molars, not erupted); moderate dental crowding in the maxillary arch (5 mm) and mandibular arch (5 mm); maxillary and mandibular incisors significantly proclined (except mandibular right central incisor, retroinclined). Maxillary and mandibular arches presented narrow "U" shape. Tongue interposition between maxillary and mandibular dental arches in rest position and tongue thrust during deglutition were detected.

The patient presented leptoprosopic face and convex soft tissue profile; acceptable nasolabial angle and good chin projection; lip sealing, with lips slightly protruded.

TREATMENT PLAN AND APPLIED ORTHODONTIC MECHANICS

The treatment objectives were: promote counterclockwise mandibular rotation, to reduce the anterior inferior facial height; increase the chin projection; improve the facial profile, decreasing facial convexity; maintain canines and molars in Class I; achieve adequate overjet and overbite, and correct dental crowding in both dental arches.

Maxillary and mandibular first premolars extractions, and vertical control for molar extrusion during space closure orthodontic mechanics were planned. Intermaxillary elastics would be used when necessary. Orthodontic retention (removable and lower fixed) for at least 12 months after removal of the fixed appliance.

Pre-adjusted brackets and tubes (0.022-in, MBT prescription, American Orthodontics, Sheboygan, WI, USA) were installed in all the teeth, including second molars. Alignment and leveling were achieved

Figure 1 - Initial facial and intraoral photographs.

Figure 2 - Initial panoramic radiograph.

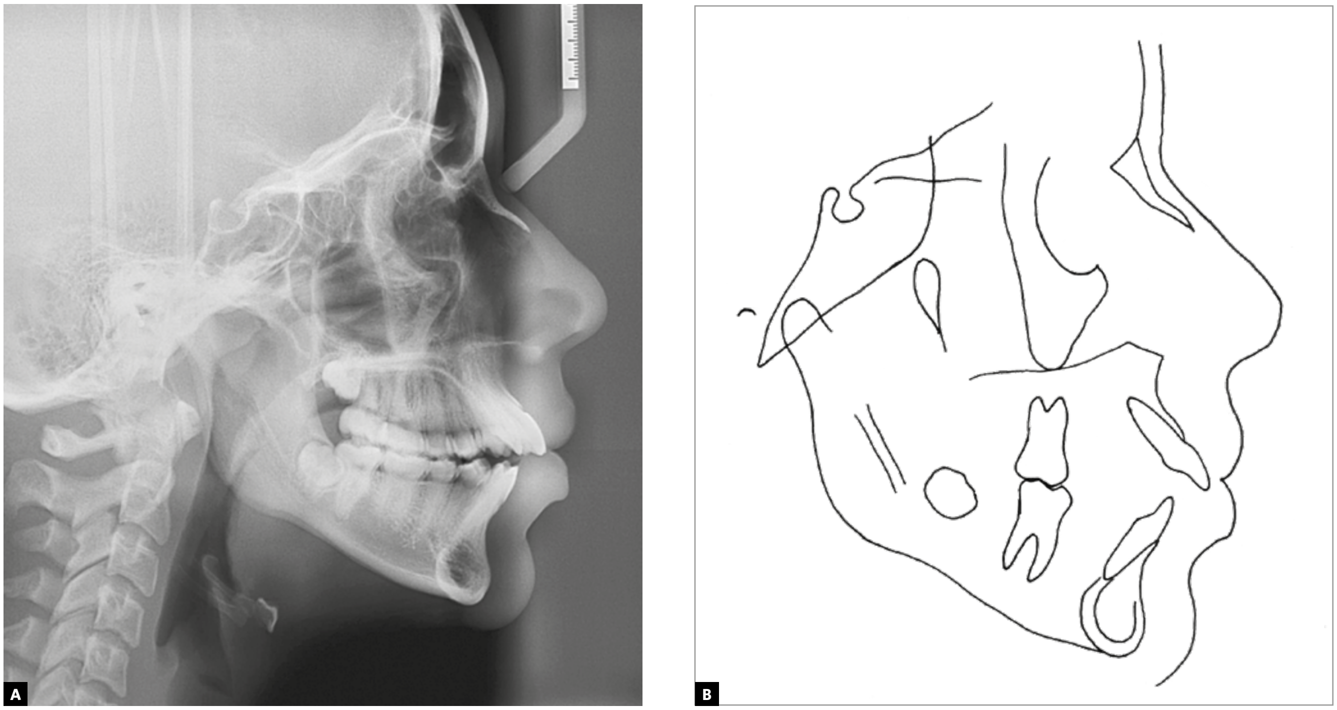

Figure 3 - Initial cephalometric radiograph (**A**) and cephalometric tracing (**B**).

with NiTi and stainless steel wires. Extraction spaces closure was performed with 0.017 x 0.025-in stainless steel archwires (upper and lower) with bull loops, and minimal gable bends. Class II elastics (3/16-in heavy) were applied 14 h/day during three months, to differentiate forward movement of mandibular and maxillary molars (mandibular molars having more anchorage loss than maxillary molars). Artistic bends were made in the stainless steel archwires. Inter-maxillary elastics (3/16-in light) were used as needed in the posterior segments, for occlusal settling.

Retainers were installed no later than three weeks after fixed appliance removal. Check-up for occlusal relationships (and possible adjustment of occlusal interferences) was made no later than four weeks after retainers had been installed (Fig 4). For retention, a 0.75-mm Essix (Dentsply Raintree, New Orleans, LA) was installed in the maxillary arch, and a 1.0-mm Essix was installed in the mandibular arch. In the mandibular arch, a 0.018-in multistrand wire was also bonded to the canines only, as an adjunct fixed retainer. The patient was instructed to wear the removable retainers for 22 hours/day (except for than meals) for at least 12 months.

TREATMENT RESULTS

Class I was maintained, and anterior open bite and overjet were corrected, with significant uprighting of the maxillary and mandibular incisors ($\underline{1}$.SN difference = 18°; $\underline{1}$-NA difference = 7 mm; $\overline{1}$.MP difference = 11° and $\overline{1}$-NB difference = 4 mm). Furthermore, correct relationship among maxillary and mandibular incisors was achieved. Dental crowding, dental rotations and unlevelled margin ridges were corrected (Figs 4 and 5).

Vertical change of the maxillary incisors was mainly due to the orthodontic mechanic. Two extra millimeters were left forecasting some grinding of incisor mamelons. Change in the position of the maxillary molars, without extrusion, was mainly due to the controlled space closure mechanics.

The maxillary intermolar distance was maintained, and slight decrease occurred in the mandibular one (1 mm). Maxillary and mandibular intercanines distances were minimally increased (1 mm).

Figure 4 - Final facial and intraoral photographs.

Figure 5 - Final panoramic radiograph.

The facial profile did not change significantly, but there was a slight decrease in the facial convexity and the lip sealing was maintained. Moreover, a slight decrease in the lower anterior facial height and some slight anterior chin projection were due to anterior mandibular rotation (Fig 6). The total and partial superimpositions show minimal reminiscent facial growth, including dentoalveolar changes (Fig 7). Small skeletal changes occurred, other than the significant reduction of the incisors anterior projection.


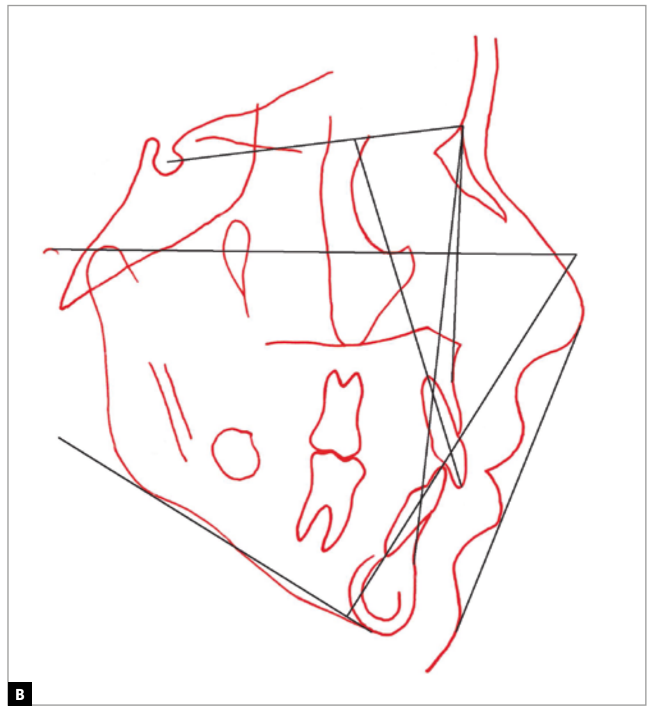

Figure 6 - Final cephalometric radiograph (A) and cephalometric tracing (B).


Figure 7 - Total (A) and partial (B) superimpositions of initial (black) and final (red) cephalometric tracings.

Table 1 - Cephalometric measurements, comparing initial (**A**) and final (**B**) lateral radiographs.

	Measurement		Normal	A	B	A/B diff.
Skeletal pattern	SNA	(Steiner)	82°	81°	81°	0
	SNB	(Steiner)	80°	77°	77°	0
	ANB	(Steiner)	2°	4°	4°	0
	Wits	(Jacobson)	♀ 0 ± 2mm ♂ 1 ± 2mm	0mm	1mm	1
	Angle of Convexity	(Downs)	0°	7°	8°	1
	Y-Axis	(Downs)	59°	63°	63°	0
	Facial Angle	(Downs)	87°	84°	85°	1
	SN.GoGn	(Steiner)	32°	41°	39°	2
	FMA	(Tweed)	25°	33°	31°	2
Dental pattern	IMPA	(Tweed)	90°	102°	91°	11
	$\underline{1}$.NA (graus)	(Steiner)	22°	36°	18°	18
	$\underline{1}$-NA (mm)	(Steiner)	4mm	10mm	3mm	17
	$\overline{1}$.NB (graus)	(Steiner)	25°	40°	27°	13
	$\overline{1}$-NB (mm)	(Steiner)	4mm	7mm	3mm	4
	$\frac{1}{1}$ - Interincisal Angle	(Downs)	130°	100°	131°	31
	$\overline{1}$ - APg	(Ricketts)	1mm	6mm	2mm	4
Profile	Upper lip-S line	(Steiner)	0	-2mm	-3mm	1
	Lower lip-S line	(Steiner)	0	4mm	-1mm	5

DISCUSSION

For subjects presenting facial hyperdivergence, mandibular posture is an important etiologic factor involved.[1,42] During active craniofacial growth, postural deviations can be improved by neuromuscular re-education, and this is the core concept of the application of orthopedic appliances. Therefore, at least hypothetically, in patients with good facial growth potential, counterclockwise mandibular rotation can partially improve the initial hyperdivergent scenario. But in adult patients, strictly speaking, there are just two possible therapeutic alternatives: 1) dental extractions as a method of camouflage or, 2) an orthodontic-surgical approach.

Premolar extractions can improve lip and dental protrusion.[43] And this happened in the current case, since the patient's final facial profile has become very pleasant. Such effect is contradictory to the common sense that extractions damage facial profiles. When well indicated, extractions can definitely improve facial harmony.[44]

In this current case, all the treatment objectives were successfully achieved after four first premolar extractions: Class I was maintained in the molars, and fully accomplished in the canines; overjet, anterior open bite, and dental crowding were corrected; tongue trust was eliminated, and facial profile convexity was slightly reduced. The final overbite was planned to allow long-term incisal mamelons wear (final overbite of 4 mm, considering that 2 mm – 1 mm of upper incisors and 1 mm of lower incisors – will be ground at a constant and steady pace, with the prospective incisors occlusal function).

Mechanically, when premolar extraction sites are orthodontically closed by *en masse* movements, two basic effects are expected: 1) loss of anchorage

Figure 8 - Intraoral photographs, 2 years after completion of fixed orthodontic treatment.

of the molars, unless prevented by anchorage methods, and 2) loss of anterior vertical dimension, due to direct or indirect extrusion of the maxillary and mandibular anterior teeth. Such loss of vertical dimension was prevented by gable bends incorporated in the used archwires. However, in open bite cases, such loss of vertical dimension is welcome exactly because it closes the bite. With minimal or no gable effect in the archwires, the open bite was corrected. Passive tongue interposition between maxillary and mandibular incisors and tongue thrust, that in open bite cases are drawbacks, are eliminated when the relationship among maxillary and mandibular incisors is correct. However, achieved results must be monitored to avoid open bite relapse.

In practice, the risk of relapse in this case is minimal, if any: first of all, good occlusion was obtained (and there is a tendency to be maintained); secondly, the initial muscular pattern, in special of the tongue, was re-established; lastly, because the patient shows great compliance with the wear of removable retainers. A minimal occlusal adjustment was performed six months after debonding. Such fine-tuning is essential to maintain the balance of the occlusion. Two-year follow-up photographs show good stability (Fig 8).

In children and adolescents, anterior open bites with tongue thrust can be treated by fixed or removable appliances, with or without lingual spurs and cribs.[45-47] However, anterior open bites in adult patients are considered skeletal, since the positioning of the anterior teeth implies in permanently deformed dentoalveolar bases and, most of the time, malocclusion is treated with fixed orthodontic appliances and intermaxillary elastics.[48]

Indeed, an orthodontic-surgical approach, with mandibular advancement and counterclockwise rotation of the occlusal plane, can be an alternative therapeutic plan for these cases[49] But orthognathic surgeries involve extra costs and risks, and provide no full guarantee of long-term stability. Some professionals would claim that orthognathic surgery is the primary option for patients with hyperdivergent retrognathic phenotype, being the premolar extractions option an alternative treatment plan. However, the author of the present report believes the opposite: The premolar extractions choice is the first therapeutic option for young adult patients, mostly teenagers, been orthognathic surgery reserved for selected cases.

The American Board of Orthodontics Discrepancy Index (ABO-DI)[50] was 39, being this case considered severe mainly because of the hyperdivergent facial phenotype, the presented open bite, and dental crowding. The American Board of Orthodontics Cast-Radiograph Evaluation,[51] when applied on the final records, scored 3. Therefore, it has been considered that the orthodontic treatment was well succeeded.

CONCLUSION

The first premolar extractions therapeutic approach is valid and may be considered the main treatment option for young adult patients presenting hyperdivergent retrognathic phenotype.

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Space closure using aligners

Ricardo Martins **Machado**[1]

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Introduction: Due to the search for more aesthetic and comfortable alternatives to perform orthodontic treatments and to the great technological development, orthodontic aligners have assumed great importance. More and more complex treatments have been carried out with these appliances without, however, having all aspects involved in their use being studied in depth. Its biomechanical planning requires different approaches than those used in fixed orthodontics, as the force systems involved in movements, responses and side effects are distinct, and the professional must be prepared when opting for the technique.

Objective: The objective of this article is to perform an evaluation of the force systems created on the space closure with aligners, its characteristics, and problems, as well as make some suggestions to overcome the difficulties inherent to its use.

Conclusion: Space closure with aligners is possible, but depends on the correct selection of the patient, in addition to requiring the proper planning of the applied forces. The use of auxiliary resources and overcorrections to address the deficiencies of the aligner systems should always be considered. Digital planning should be used as a map of the force systems that will be applied, and not just as a marketing tool, keeping in mind that determining the objectives and the way to achieve them is the responsibility of the orthodontist, and that treatment plans must be individualized for each situation, following appropriate biomechanical precepts.

Keywords: Esthetic aligners. Invisalign. Removable orthodontic appliances. Clear dental appliances.

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

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INTRODUCTION

Since the first vacuum-formed plastic orthodontic device for dental alignment was proposed by Kesling[1], there has been a great advance in the possibilities of treatment with this type of appliance. This idea was put aside for many years until it was taken up by Ponitz,[2] in 1971, who suggested the making of vacuum appliances made with transparent material on plaster setups. Following a similar principle, McNamara et al[3] suggested tooth movement with aligners; and in 1993, Sheridan[4] introduced the Essix system, which uses the technique of bubbles and bumps, created with reliefs and deformations in the models, made with heated special pliers, to move teeth. In 1997, two Stanford MBA students, without any dental training, applied their knowledge in computing and CAD/CAM technology to develop and launch the Invisalign system of aligners based on digital technology. Since its creation, encouraged by the success of Invisalign and the easier access to this kind of technology, several other aligner systems have been created by other companies, using the same principle. The current market presents a huge variety of digitally produced systems, with great appeal to the public.

Plastic aligners have great esthetic advantage, more comfort and make it a lot easier to keep a good oral hygiene, when compared with traditional fixed appliances,[5] with ease of feeding and chewing being the most highlighted qualities referred on studies[6]. Previously having it's use restricted to simple movements to align incisors, the plastic aligners have been broadening its applications and are now used to treat almost every kind of malocclusion, including more complex cases, with good esthetic and functional outcomes.[7] In many situations aligners can be as efficient as fixed appliances, even though in other cases they still lack some improvement, like torque control or proper occlusal settlement.[8]

In this scene, the companies that produce those aligners have been funding lots of researches for development of new materials and technologies to supply the orthodontists needs. The great evolution of software for digital planning allied with the use of artificial intelligence and more sophisticated algorithms allow more precise and predictable outcomes of the force systems generated by these devices, proposing more reliable solutions.

In the introduction of any new technology a sequence of events can be observed. The first phase is the trigger of the innovation, when it appears on the market, presented as the best solution for all problems. Seduced by all the positive aspects massively highlighted by the developers, professionals start to try to use it in some situations. The use of the technology experiments a dramatic increase. The manufacturing companies then start to invest more and more in publicity. Stories of success begin to pop up on various fronts, making other professionals feel confident to start using it as well, hoping for wonderful outcomes. This phase is called peak of inflated expectations. As it is used without thorough evaluation and concern to the restrictions in its indications of use, failures to achieve the expected outcomes begin to be reported, because the limits of the technique are still uncertain. At this point, a feeling of disillusionment begins to set in and many abandon its use. It is called the through of disillusionment. We then enter a slope of enlightenment, where more scientific studies and trials are made, bringing better understanding of the actual pros and cons of the technique and, after a period of maturation where the limitations and methods are better defined, the technique finds its place among the tools of regular use by the professionals, who will be able to use it in all its potential on the proper situations, taking the necessary precautions to achieve the best results. This phase is called the plateau of productivity. This sequence of events is known as the Gartner's Hype Cycle for new technologies,[9] as shown in Figure 1.

This situation can be verified in the adoption of the aligners. The planning of orthodontic movements must be made differently if compared to fixed ortho-

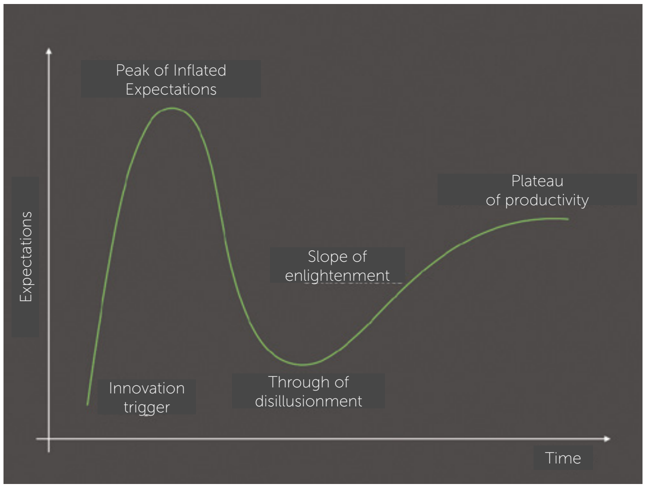


Figure 1 - Gartner's Hype Cycle for new technologies.[6]

dontics, and the desired and undesired effects of each force system will depend on other factors. Because of that, orthodontists with traditional background on fixed orthodontics will need to adapt, if they wish to use the aligners and achieve results as they are used to. Thus, the objective of this article is to perform an evaluation of the force systems created on the space closure with aligners, its characteristics and problems, as well as make some suggestions to overcome the difficulties inherent to its use.

PATIENT SELECTION AND ORTHODONTIST'S ATTITUDE

Regardless of all the high technology behind clear aligners, the most important criteria for success in the treatments falls under properly choosing the patient. Some clinical conditions, such as dental open bites, are more prone to be successfully treated by aligners, while others, like deep bites associated to spacing, are more difficult to be treated, but above it all, the orthodontist must be able to correctly evaluate the psychological and behavioral profile of the patient, to identify the degree of engagement and motivation. Since aligners are removable appliances that need to be worn continuously, the treatment demands high level of discipline and commitment to achieve the objectives planned. A perfect biomechanical planning and all the technology involved have no use if the patient is not adherent to the treatment and the aligners are not correctly used. It is very important that the communication between orthodontist and patient is extremely clear, and that the patient take co-responsibility for the success of the treatment, considering that a great part of it depends on that.

Maybe this last issue is the main reason why orthodontist resist to adopt aligners as a routine option, since they consider having less control over the results, when compared to fixed appliances, which depend less of patient collaboration.

The orthodontist who decides to start using aligners must have in mind that, besides having to motivate the patient during the treatment, will have to take a more proactive attitude while planning, anticipating the possible side effects of the chosen biomechanics. Differently from the fixed appliances, where they have the possibility to be more reactive and correct it at each visit, depending on the response to activations made on the previous appointment, on the treatment with aligners the orthodontist has the activations predetermined and all the compensations must be created before the movements are made. For this reason, it is of utmost importance a deep knowledge of the system characteristics and all the effects of intended biomechanics. Just as individualization on bracket placement and archwire sequences on fixed appliances according to the objectives of the treatment, with aligners we should be able to clearly visualize where to go and how to fulfil each step of the treatment to correctly prescribe the movements and auxiliary resources, as well as understand the limitations of each case. That is why, despite the smaller chair time during treatment, the time invested in the construction of the treatment plan tends to be bigger and demands great dedication.

DIGITAL SETUPS

The first dental movements made with aligners were made over physical setups or small sequential modifications on plaster models, on which the aligners were vacuum-pressed. Activations could be done also by special pliers causing controlled deformations on the aligners to create pressure points that would cause the desired tooth movement. These techniques were very laborious and had very little precision. The introduction of the digital models in orthodontics had a very important role in the dissemination of aligners. Its precision and accuracy have already been proved in many studies[10,11] and they have been gradually replacing the plaster models. Every treatment with aligners is based on movements made on digital models, that are divided in stages by software specifically designed for that purpose, which is made respecting the physical properties of the material of which the aligner is made and the limits of the biological response of the patient. The planning systems are becoming more sophisticated, using the huge databases created by the initial, follow-up and final records of millions of cases treated worldwide, to harvest lots of information over the tooth movements and the responses to activations. Using artificial intelligence and machine learning resources to treat these data and feed the algorithms, the treatment plans provided are becoming more and more reliable.

One of the greatest indirect advantages of the massification of the aligners use was the dissemination of the use of digital setups, imperative for their manufacturing. Different companies have different resources to perform aligners staging, and this interface became a high value asset for the elaboration of the treatment plans and to the communication between the orthodontist and the team that produces the aligners, but it can also be used, in many situations, for fixed orthodontics cases, like in trays for indirect bonding, for instance. The digital setups can also be used to improve the communication between orthodontist and patient, providing a way to visualize the treatment goals and its phases. But is this last one the best way to face these softwares? As simply a marketing and communication tool? When orthodontists take that attitude, one of the greatest powers of this tool, which is the possibility of constructing a detailed map of all the force system that will be applied during the treatment and the anticipation of its effects, gets set aside. The possibility to test in a practical and fast way many treatment possibilities, makes the orthodontist's choice of one treatment plan over another more conscious and safe. This visual analysis, paired with the clinical experience of the clinician, allows the planning of overcorrections, preparations, compensations, and anticipation of undesired side effects that may occur as consequence of the chosen biomechanics. By doing this, the digital treatment plan helps to minimize errors and makes treatments safer and more precise.

By the deep knowledge of the biomechanics characteristics of the appliances and dental movements, one can use many resources to achieve the planned outcomes. The results observed on aligner treatments are improving by their association with auxiliary tools, like elastics, skeletal anchorage, binaries with elastics and even the use of brackets in some segments of the arch — the hybrid treatments. By correctly using these tools, it is possible to overcome some of the limitations of the aligners and, according to the learning curve of each professional, optimize treatments and improve the predictability of the planned movements, because the undesired side effects will be reduced.

PECULIARITIES OF ALIGNER'S BIOMECHANICS

When putting together a force system for any orthodontic movement, a series of factors have to be taken into consideration, such as: the point of application of the force, the force magnitude, the velocity of application, it's direction, the duration and the effects it will produce.[12] These questions are only some that can emerge and, when treating with aligners, will have different answers, if compared to fixed appliances. An example of these differences can be seen in Figure 2, which shows a clinical case considered simple for treatment with fixed orthodontics, but that represents a great challenge to be treated with aligners. The patient had good posterior intercuspation, diastemas in the maxillary arch, accentuated overbite and good incisors exposure. The vertical control and control of buccal-lingual inclination of the incisors during the anterior retraction for space closure is a great difficulty of the aligner systems, as it causes lingual inclination of the incisors, increasing the overbite and incisors exposure. In a case like this, the results of treatment with aligners would be very unfavorable and difficult to achieve.

POINT OF APPLICATION

Instead of having the force applied to one single point at the buccal or lingual surface of the tooth, as happens in fixed orthodontics, there will be a plastic surface embracing the whole crown of the tooth (Fig 3).

The decomposition of forces must take into consideration all the tooth surface to determine the resulting force on that system. Besides that, on fixed appliances, the wire is tied to the brackets and delivers the forces by pulling or pushing the teeth (Fig 3B), while with aligners, where there is no fixed structure connecting

Figure 2 - Patient presenting diastemas with exaggerated overbite, good posterior intercuspation and good incisors exposure - example of a situation where what seems to be simple for planning with fixed orthodontics becomes a complex treatment to be performed with aligners, due to the limitations of the technique.

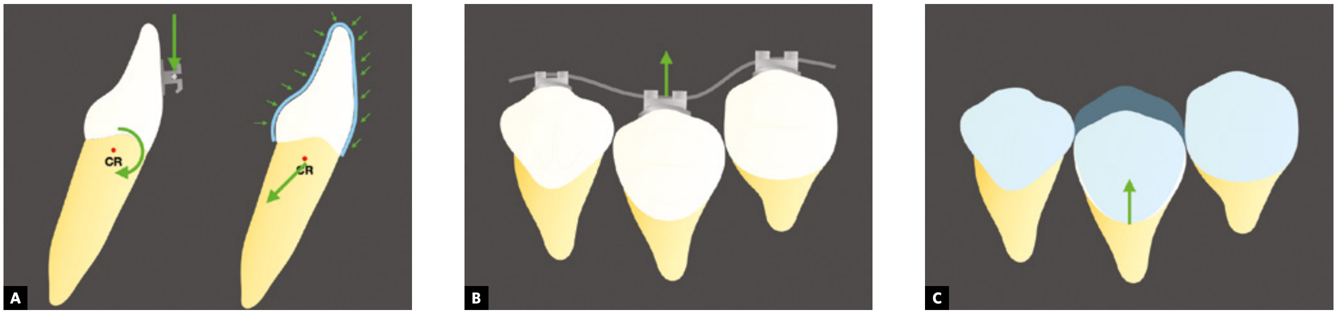


Figure 3 - Examples of the difference in points of application of forces between fixed appliances and plastic aligners during intrusion (A). The brackets and wires system push teeth toward the wire (B) while aligners pull the teeth to the desired direction (C).

the appliance and the tooth, the force is delivered by the contact of the plastic with the crown, pulling it to the desired position (Fig 3C).

Because of this characteristics, dental crown anatomy will have a great impact on the response of some tooth movements. Teeth with short expulsive crown shapes, that will have less contact surface with the plastic of the aligner, tend to express some movements less efficiently than teeth with larger and more retentive crowns. For this reason extrusion is an example of a unfavorable movement to be done with aligners,[13] while it's a simple movement to be done with fixed appliances. Canines rotation is another movement with very low predictability and must be overcorrected.[14]

ATTACHMENTS

The attachments are resources normally used to address this issue. By adding little amounts of composite with specific designs to specific areas of the crown, the dental anatomy is changed to improve the retainability and create more favorable shapes and contact surfaces to deliver the desired force. This allows that these movements occur more effectively and predictably. Unfortunately, these resources present a negative effect as well, especially in the anterior region of the dental arch, because it worsens the esthetics of the aligners, making it even worse than the esthetics of ceramic appliances.[15]

Attachments may function as retention auxiliaries, whose only intention is to keep the aligner in place, or they can be active, when the contact of the plastic with the tooth surface is supposed to deliver some force component in a specific direction. In this case, attachments have plan surfaces positioned in a way that favors the application of these forces. There is a great variety of shapes and sizes of attachments, according to each manufacturer, tooth anatomy and movement intended, as can be observed on Figures 4 and 5.

The proper selection of attachments may be a decisive factor on the predictability of the treatment, even though they are not indispensable to tooth movements in most cases. When the orthodontist chooses a specific aligner system, the algorithms in the software will have internally predefined parameters to, depending on the movements needed, suggest which attachments to use. However, this selection won't always follow the same line of thought of the orthodontist, and may prioritize different movements from the ones desired to fulfill the planned outcomes. Those algorithms work according to a certain hierarchy of movements that will determine the automatic selection of attachments, normally based on the difficulty of the movement, and not necessarily on its relevance to the final results. If the case have, for instance, a tooth that needs to be intruded and rotated, the software will prioritize the rotation and suggest one attachment that favors the rotation over the intrusion, because the rotation is a more difficult movement

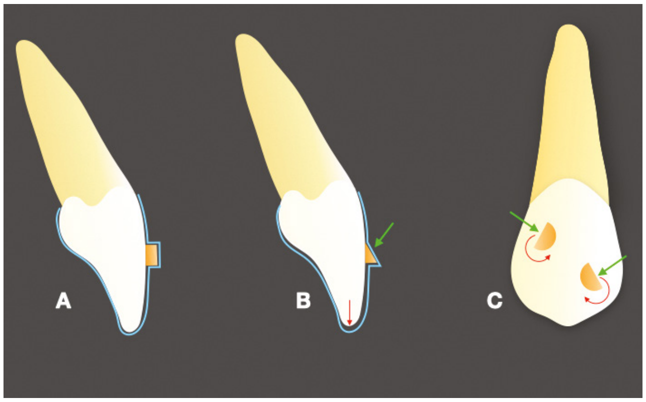
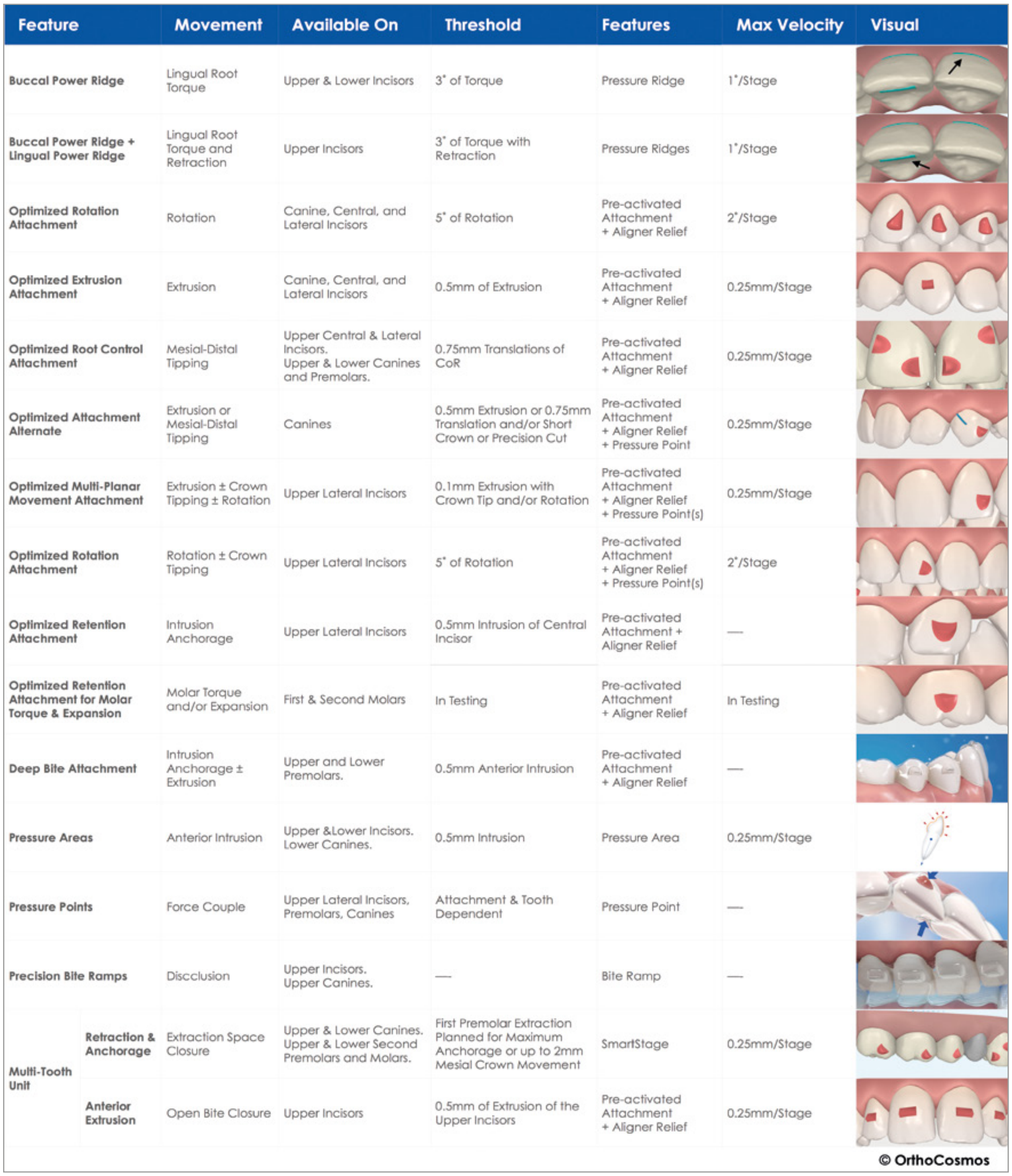


Figure 4 - Examples of attachments: (A) passive or retention, (B) optimized for extrusion and (C) optimized for root inclination. The optimized attachments show active surfaces for specific movements.



Feature	Movement	Available On	Threshold	Features	Max Velocity	Visual
Buccal Power Ridge	Lingual Root Torque	Upper & Lower Incisors	3° of Torque	Pressure Ridge	1°/Stage	
Buccal Power Ridge + Lingual Power Ridge	Lingual Root Torque and Retraction	Upper Incisors	3° of Torque with Retraction	Pressure Ridges	1°/Stage	
Optimized Rotation Attachment	Rotation	Canine, Central, and Lateral Incisors	5° of Rotation	Pre-activated Attachment + Aligner Relief	2°/Stage	
Optimized Extrusion Attachment	Extrusion	Canine, Central, and Lateral Incisors	0.5mm of Extrusion	Pre-activated Attachment + Aligner Relief	0.25mm/Stage	
Optimized Root Control Attachment	Mesial-Distal Tipping	Upper Central & Lateral Incisors. Upper & Lower Canines and Premolars.	0.75mm Translations of CoR	Pre-activated Attachment + Aligner Relief	0.25mm/Stage	
Optimized Attachment Alternate	Extrusion or Mesial-Distal Tipping	Canines	0.5mm Extrusion or 0.75mm Translation and/or Short Crown or Precision Cut	Pre-activated Attachment + Aligner Relief + Pressure Point	0.25mm/Stage	
Optimized Multi-Planar Movement Attachment	Extrusion ± Crown Tipping ± Rotation	Upper Lateral Incisors	0.1mm Extrusion with Crown Tip and/or Rotation	Pre-activated Attachment + Aligner Relief + Pressure Point(s)	0.25mm/Stage	
Optimized Rotation Attachment	Rotation ± Crown Tipping	Upper Lateral Incisors	5° of Rotation	Pre-activated Attachment + Aligner Relief + Pressure Point(s)	2°/Stage	
Optimized Retention Attachment	Intrusion Anchorage	Upper Lateral Incisors	0.5mm Intrusion of Central Incisor	Pre-activated Attachment + Aligner Relief	—	
Optimized Retention Attachment for Molar Torque & Expansion	Molar Torque and/or Expansion	First & Second Molars	In Testing	Pre-activated Attachment + Aligner Relief	In Testing	
Deep Bite Attachment	Intrusion Anchorage ± Extrusion	Upper and Lower Premolars.	0.5mm Anterior Intrusion	Pre-activated Attachment + Aligner Relief	—	
Pressure Areas	Anterior Intrusion	Upper &Lower Incisors. Lower Canines.	0.5mm Intrusion	Pressure Area	0.25mm/Stage	
Pressure Points	Force Couple	Upper Lateral Incisors, Premolars, Canines	Attachment & Tooth Dependent	Pressure Point	—	
Precision Bite Ramps	Disclusion	Upper Incisors. Upper Canines.	—	Bite Ramp	—	
Multi-Tooth Unit – Retraction & Anchorage	Extraction Space Closure	Upper & Lower Canines. Upper & Lower Second Premolars and Molars.	First Premolar Extraction Planned for Maximum Anchorage or up to 2mm Mesial Crown Movement	SmartStage	0.25mm/Stage	
Multi-Tooth Unit – Anterior Extrusion	Open Bite Closure	Upper Incisors	0.5mm of Extrusion of the Upper Incisors	Pre-activated Attachment + Aligner Relief	0.25mm/Stage	

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Figure 5 - Examples of the great variety of attachments and resources existing in the Invisalign system, which is only one of the many options available.[16]

to be done, even if the intrusion is a more important movement to the resolution of the main problem. This is where the orthodontist must have an active role in the attachment selection, and not only passively accept the suggestions given by the system. In many cases, it is necessary to change the attachments' design, dimension and position to get the desired force system.

Another factor that must be taken into consideration is the attachment building technique. They must have an excellent adaptation to be able to work properly. There are variations in size and shape of the attachment templates and the active aligners, so replacement of lost attachments or adjustments to worn out ones must be done on the provided template, never directly on the aligner. Another factor that should be taken into consideration is the proper attachment placement technique. The templates must be perfectly adapted, and the slots completely filled with the composite of choice, but without excesses, because it could prevent the aligner to seat properly in place, affecting the movement intended. If there are excesses, it is important that they are completely removed before placing the aligners on.

TREATING CASES WITH EXTRACTIONS

The boundaries of aligners treatments without teeth extractions is similar to the ones with fixed orthodontics. Severe crowding over 6 millimeters will probably cause great incisors protrusion and need significative expansion of the dental arches,[17] which may compromise the stability of the results as well as the patient's periodontal health in the long run. In these cases, it may be recommended to work with teeth extractions, normally first premolars, which can be challenging when the clinician decides to work with aligners.[18] Other examples of cases that will have to deal with space closure are the ones with other extractions and surgically assisted palatal expansion (SARPE), where a great diastema is formed on the anterior portion of the upper arch.

It is very common to find in the literature case reports of successful cases of extractions where premolars have been removed because of severe crowding, but these cases normally do not need much retraction of the anterior teeth. The torque control of the incisors during retraction, a critical point in any retraction, even with fixed appliances, poses an even tougher challenge in aligner therapy, due to its physical properties. Some studies suggested that side effects of treatments with extractions, more specifically the tipping of the teeth adjacent to the extraction spaces, should be corrected with fixed appliances, what would considerably increase treatment time.[19]

When considering space closure, some possibilities may be present. The space closure can happen with: maximum anchorage, where all the space will be consumed with anterior retraction; reciprocating movement, where part of the space will be used for anterior retraction and the rest of it will be closed by mesial movement of the posterior segment; or it can be closed mostly with mesial movement of posterior teeth without any anterior retraction, just by solving some anterior crowding, for example. On the next paragraphs, we will analyze the first and second situations.

1 — CASES OF MAXIMUM ANCHORAGE CONTROL

On the situations where the space closure must be done exclusively by retraction of anterior teeth, the clinician must take extra care. The anchorage control must be planned thoroughly and the use of resources such as miniplates or mini-screws should be taken into consideration as a valuable ally. They would help not only in the sagittal direction, but also help control the vertical movements. If the clinician chooses not to use those resources, he should be even more careful.

The elastic properties of clear aligners, similar to what would happen if, with fixed appliances, anterior retraction was made on a thin NiTi wire, would generate a clockwise force moment in the anterior part of the arch that would cause the incisors to incline lingually and extrude. The middle part of the arch will receive intrusive force components, that will tend to intrude the premolar and cause the molar to tip forward, due to the counterclockwise force moment in the posterior segment. With the extrusion of the incisors, interferences are created in the anterior area and a posterior open bite is set.

This happen because the plastic will suffer horizontal deformation, like a wooden arch whose tips are connected by a wire and pulled towards each other. The fact that, due to the extraction site, the aligner has a segment without tooth support, it is even more prone to deflect (Fig 6).

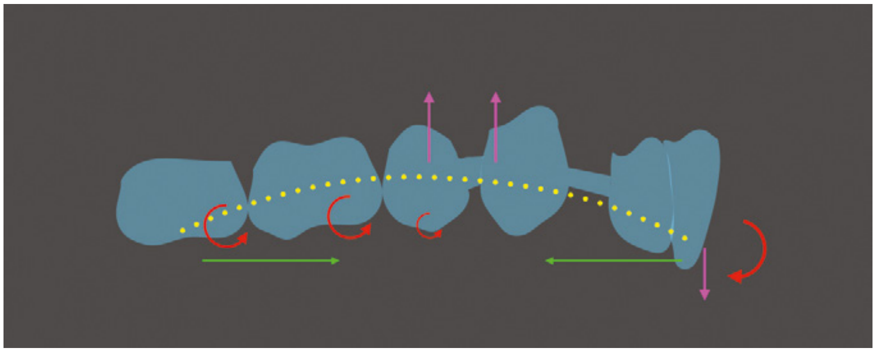

Figure 6 - Force diagram showing the bow effect that happens during the anterior segment retraction with aligners, causing intrusion of the middle segment, mesial inclination of molars and extrusion with lingual tipping of the incisors.

As a result, if no action is taken to prevent that, the overbite will increase considerably while an open bite is settled in the posterior segment. When working with fixed appliances, similar effects could happen if the retraction was made with thin elastic wires, and the solution would be working with thicker and stiffer wires, to avoid the bow arch effect. With aligners, the material is the same through all the phases of treatment, so the only resource left to be used is to vary the way the forces are applied. With this in mind, the dentist can use some of the following strategies:

a) Add curves of Spee

Following the same logic used in fixed appliances, one can plan a reverse curve of Spee on the lower arch and an exaggerated curve of Spee on the upper arch during the movements. This is made by planning some extrusion of the premolars, buccal inclination of the incisors' crowns, intrusion of the incisors and distal tipping of the molars.

Since an intrusive effect will be planned for the incisors, the aligners won't tend to lose tracking on those teeth; but in the middle section of the arch, where the premolars will be the vertical anchorage for the incisors movement, the extrusive force might cause the aligners to lose grip, damaging the expected results. Besides being the anchorage, some extra extrusion will be planned to compensate the bow arch effect. As discussed before, extrusive movements are difficult to be made by aligners because of the expulsive shape of teeth crowns. On this matter, the use of attachments can considerably improve the retention of the aligners and allow the movements to happen as planned.

Another possibility that can be adopted alone or combined with the attachments, depending on the tooth anatomy, is to use a vertical intermaxillary elastic on the maxillary and mandibular premolar, over bonded buttons. The extrusive force of the elastics will oppose the intrusive force generated by the aligner, balancing the force system and keeping the aligner well adapted. Some authors recommend the use of bite ramps on the lingual surfaces of the maxillary incisors to help the intrusive effect on the mandibular incisors; but, during anterior retraction, where the lingual inclination of the incisors is already challenging, the occlusal contact on those bite ramps would generate a force applied lingually to the center of resistance of the incisors, that would cause a force moment that would make them tip lingually, worsening the final outcome.

b) Use movement staging

To gain more control over movements, they can be divided in stages. For instance, we can alternate between periods of distalization and periods of pure extrusion of the canines during retraction, reducing the chance of tracking loss, because in between distal movements the aligner has the time to express the movement of crown *versus* root tipping and the vertical control. Taking a closer look at this approach, it mimics what happens in the interaction between the wire and the brackets during sliding mechanics. At first, a crown inclination will occur and the binding generated between the bracket and the wire will generate a force moment that will move the root and upright the canine during the time between activations. After a period of this alternation of movements, a bodily movement will be achieved. With aligners there will be first a tendency to tooth inclination and intrusion (due to the bow arch effect), but if this tooth is kept without a new activation for distalization, it will have time to express only the compensatory movement, while another segment of the arch can be activated.

The inclination control can also benefit from this alternation of active and inactive distalization periods. For that to happen, the use of attachments on the teeth to be moved will be of great help. When the first inclination occurs, the little unsettling that will take place inside the attachments pod of the aligner will create additional forces that will tend to upright the tooth. Some companies provide active attachments with this goal, but a similar effect can be achieved with regular attachments properly placed, since the elastic force of the aligner mismatch will make it active.

As said before, between the activations for distalization of the canines, we can work on other aspects of the movements in a synergistic way, like the intrusion and the buccal inclination of the incisors, the distal inclination of the molars, or, if that is the case, the resolution of anterior crowding that might be present.

The professional can work dividing all the anterior retraction in periods of canine distalization combined with incisors intrusion and protraction, alternated with partial retraction of the incisors. This approach, depending on the needs of each case, could be associated with the use of intermaxillary elastics, which would provide more control of the undesired effects that may appear, therefore, making the movements more predictable.

Clinical case 1

On Figure 7, we can see a patient with severe crowding on both arches, increased overjet, good molar relationship, mandibular deficiency, and vertical pattern. She had a 20% overbite and good periodontal health. The main indication was an orthognathic surgery with mandibular advance, which she refused. It was then decided to perform a compensatory treatment with aligners —a demand of the patient— with the extraction of the four first premolars. The space would be used for resolution of the crowding and incisors retraction on both maxillary and mandibular arches. Despite the weaker facial esthetic result, this was the option chosen by the patient, who refused any orthognathic surgical approach.

After a first set of 43 aligners, the patient, who was extremely compliant with the aligners use, had the extractions spaces closed, but with open bite on both sides on the premolars and first molar areas, and very increased overbite (Fig 8). The molars' crowns were tipped mesially and, due to the excessive overbite, all lateral movements had major interference of the incisors.

A new set of 37 aligners was planned, for maxillary and mandibular incisors intrusion, premolar extrusion, correction of the molars crown tipping, lower midline correction to the right and mesialization of the left posterior mandibular segment. Cuts for Class II elastic on the left side were made on the six last aligners to help lower midline correction and improve the molars and canines relation.

Figure 7 - Female patient, 24 years of age, with bimaxillary protrusion and severe crowding on both arches, who chose to be treated with four first premolars extraction and compensation with aligners.

Figure 8 - Situation at the end of the first aligners sequence. The curve of Spee was deepened with incisors extrusion and mesial inclination of molars and posterior open bite.

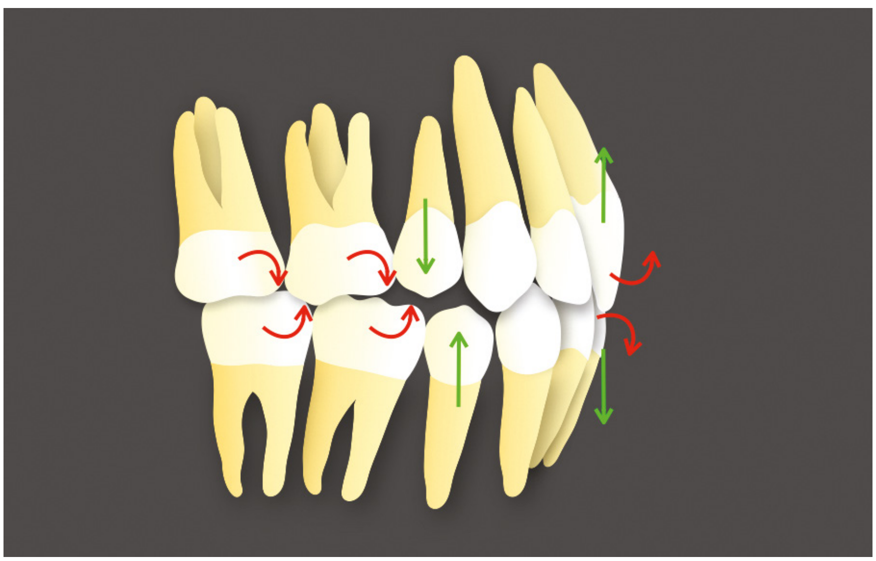

Figure 9 - Force system planned for the second set of aligners.

The force system planned for this set is represented on Figure 9. The patient, although very compliant with the use of the aligners, did not use the elastics as recommended.

The final result showed good occlusal relations, with good root parallelism, 50% overbite, complete closure of the overjet and complete space closure. Despite the incisors intrusion did not happen completely as planned, the protrusive and lateral movements guidances were correctly established, as can be verified in Figure 10. This case showed good finishing parameters and was presented and approved by the Brazilian Board of Orthodontics.

Going through cephalometric superimpositions, we can verify that there was no mesial movement of the maxillary posterior segment, but a slight mesial movement of the mandibular molars. The incisors became more vertical and the mandibular incisors were intruded. The compensatory retraction of the maxillary incisors caused a relative extrusion, due the lingual inclination of the crowns, as expected (Fig 11).

C) Use of auxiliary mechanics

The aligners systems alone still need further developments to treat more complex malocclusions, such as ex-

Figure 10 - Final photographs of the patient, after the second set of aligners.

tractions cases.[18] That is why the auxiliary resources are so important. As an example, we can take the use of skeletal anchorage on cases where you cannot afford to have any mesial movement of molars. It would make the outcome much more predictable. Miniscrews or miniplates would favor the distalization of the anterior segment without any anchorage loss, having the option of using power arms on the canines to better control the moment of force created, and reduce the undesired effects on the anterior segment.

The use of intermaxillary elastics can also provide more control during space closure. On cases where you have a good mandibular arch but extractions are needed on the maxilla, the use of Class II elastics supported on the mandibular first molars and on the maxillary canines during their distal movement can be an excellent alternative to reduce the bow arch effect. The vertical component of force generated by the elastic would help control the tendency of intrusion in the middle section of the arch. The use of elastics can be started at any point during the treatment, but, if it's present during the distalization of the canines, we have the advantage of force component that pulls the tooth towards the aligner, making it harder to lose tracking. Similar to what happens on fixed appliances treatments, the intermaxillary elastics can also be used for better anchorage control, avoiding mesial movement of the posterior teeth.

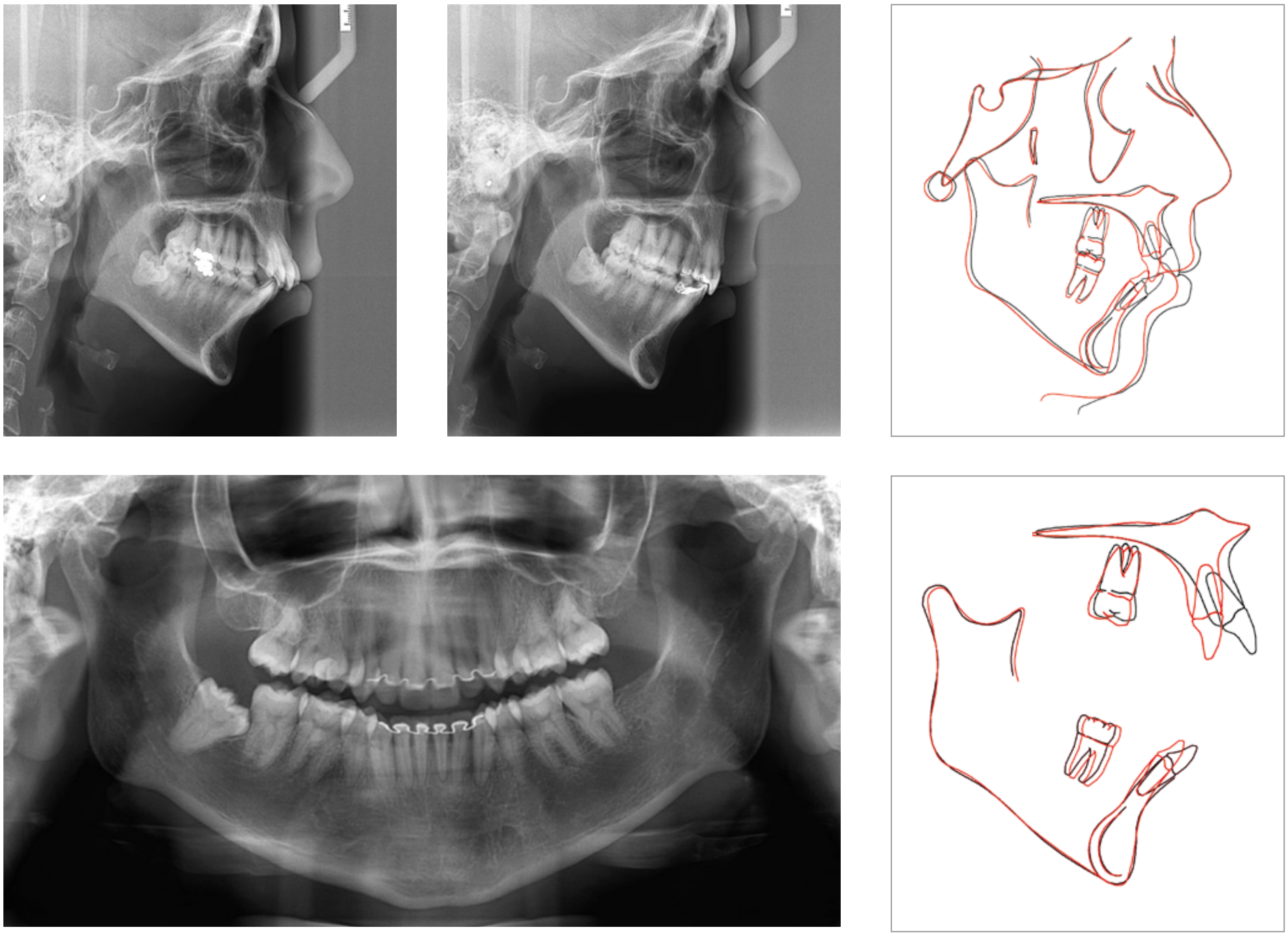

Figure 11 - Final panoramic and cephalometric radiographs with superimpositions.

On space closure between teeth with divergent roots, or in the need for uprighting an inclined tooth, the power arms can be an excellent alternative, since they will balance the moments generated by the aligners. On Figure 12, a case of space closure after a surgical-assisted rapid palatal expansion (SARPE). One can notice that, in spite of the presence of attachments meant to control the root movement, the space closure between the central incisors was happening mainly by mesial inclination of the crowns, causing massive tracking loss of the aligners. In order to revert this situation, power arms made of stainless steel 0.020-in wires were bonded on the lingual surface of the central incisors and a cut was made on the aligners. These power arms were divergent and were activated by a chain elastic pulling them together. Since the power arms raised above the center of resistance of the incisors, it created compensatory moments, contrary to the ones created by the aligners, who were inclining the teeth mesially. It corrected the excessive inclination of the incisors and allowed a more controlled space closure.

As discussed earlier, the virtual setup will allow us to analyze the force system step by step and will help us draw a clear map of the biomechanics applied to each step of the treatment. On cases with great incisor retraction, at the end of the planning, the setup will display an anterior open bite, with proclined incisors and molars with distal tipping. These overcorrections are important to be added but, by adding them, the final setup won't be a reflection of the final occlusion planned by the orthodontist, which may raise, if the orthodontist decide to show this setup to the patient, some doubts and insecurities related to treatment outcomes. If the orthodontist or the patient thinks it is imperative to see the final outcome planned, it can be a good solution to create an ideal setup, with the final occlusion planned just to explain to the patient the treatment objectives and promote better communication and understanding.

Figure 12 - A) Patient after SARPE, starting treatment with aligners. B) Tracking loss due to excessive mesial inclination of the crowns of the incisors. C) Divergent roots. D) Power arms placed to be used along with the aligners. E) Detail of active power arms. F) Improvement of tracking. G) By the end of the aligner set (a new set of aligners was planned then for better finishing).

2 – CASES WITH RECIPROCAL SPACE CLOSURE

On cases where some mesialization of the posterior segment simultaneous with the anterior retraction is desirable, the movements in the sagittal plane work synergistically, meaning that the reciprocal anchorage would tend to favor both movements, optimizing the treatment. Even though this is true, there is also the risk of some of the side effects are potentiated due to the high elasticity of the aligners.

The moment of force created by the mesialization of the molars tends to cause intrusion of their mesial cusps, with consequent mesial inclination of the crowns. The effect on incisors is also similar to the described earlier for maximum anchorage cases. Being so, the same precautions can be made with some minor adjustments.

Clinical case 2

Figure 13 displays a case where, specially on the maxillary arch, the movement was made in a reciprocal way. The patient showed Class III molar relationship, anterior open bite, spacing and biprotrusion, being these last two his main complaints (Fig 13A). For the treatment, it was necessary three aligner sequences. The first set had 51 pairs of aligners, where only vertical attachments on canines and premolars were used to avoid crown tipping during the space closure. Since the staging of the movements was not properly done, the side effects discussed earlier were present and intense, especially with molars and premolars inclination, deep bite, extrusion, and lingual inclination of the incisors. On the mandibular arch, where there was more anterior retraction, the negative effects on the incisors were more evident. On the maxillary arch, since there was more mesialization of molars to correct the molar relationship, their inclination and intrusion was much more noticeable, which can be seen in Figure 13B.

A second sequence of 16 pairs of aligners was ordered to correct these problems and improve the case finishing. By that time, the provider released optimized attachments for root control, such as the ones described in Figure 4C, for root control, so it was decided to make an attempt of correcting the teeth inclinations with these attachments, instead of the vertical ones used in the first set.

Figure 13 - Clinical evolution of a reciprocal space closure, from initial condition (**A**); to the end of the first set of 51 aligners (**B**); after the second set of 16 aligners (**C**); and the final result, after the last sequence of 21 aligners.

The results were not satisfactory, as it can be seen on Figure 13C, and a third set with 21 pairs of aligners was ordered, but this time with cuts for buttons bonded on the first molars for intermaxillary elastic use simultaneously with the aligners. The use of vertical elastics was kept for 45 days after the removal of the aligners for better settling of the occlusion, after which, treatment was finished with proper molar relationship and better inclination of incisors. The overbite was still deeper than the ideal, even though there was no interference with lateral or protrusive disocclusion guidances. Figure 14 displays the initial and final cephalometric radiographs and superimpositions.

Further improvement of the deep bite would demand a new set of aligners, which was refused by the patient, claiming to be completely satisfied with that result, both esthetically and functionally. This situation is common during the learning curve with aligners and makes it very clear why the professional must have a deep knowledge of the aligners biomechanics, the effects of its resources and be much more proactive during the treatment planning and anticipate the possible side effects of the chosen biomechanics. If the orthodontist waits until the end of the aligners set to see what went down different from planned, and only then take corrective actions, this will make treatments with high risks of side effects much longer. If we consider that aligners treatments are completely reliant on patient compliance, in longer treatments we risk having this cooperation worn out and the compliance reduced.

When used only as anchorage units, the molars will already tend to incline mesially during retraction of canines and incisors. On cases where there will be a force to move molars mesially, this tendency will be even bigger. That is why it is

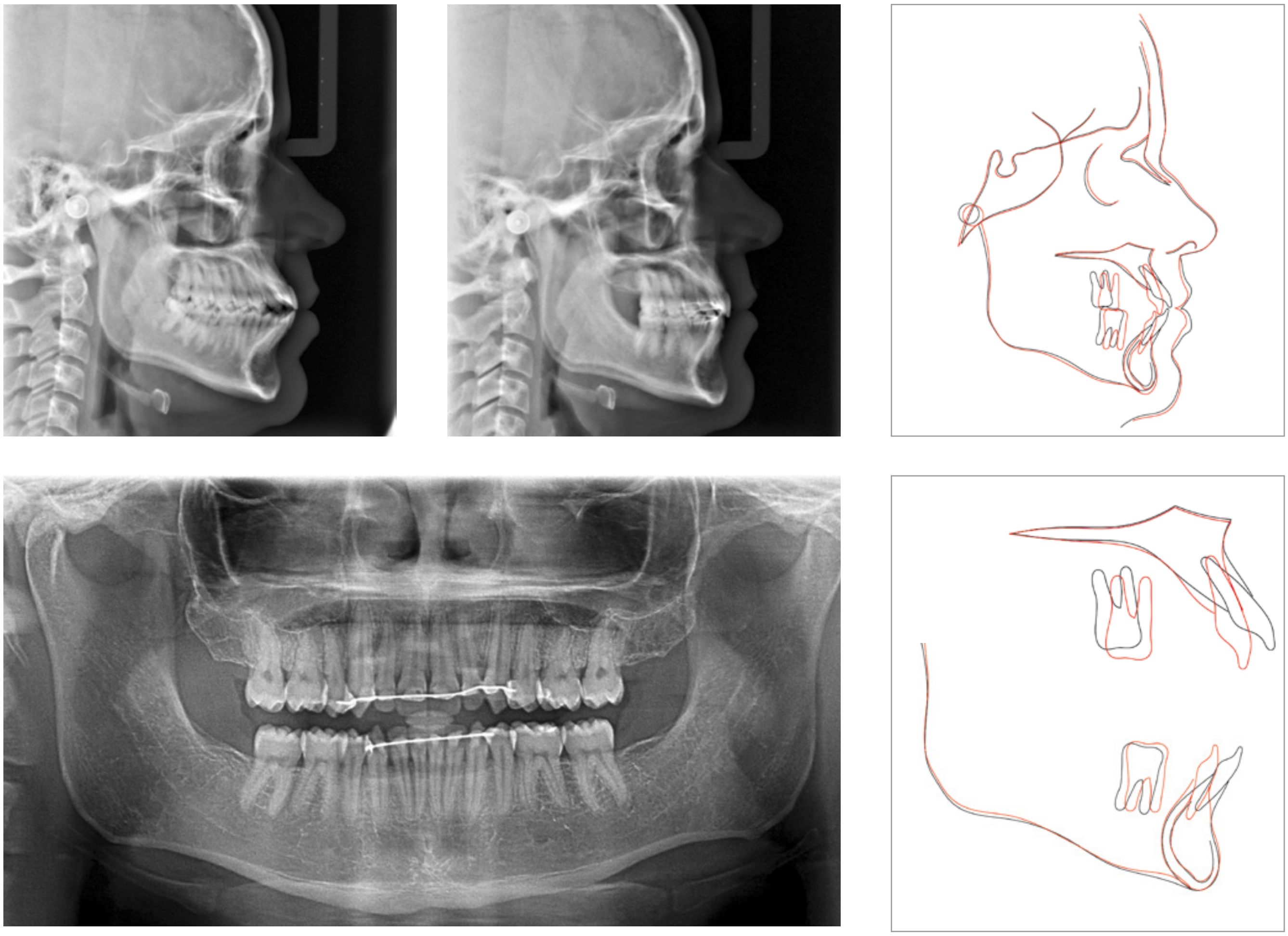

Figure 14 - Final panoramic, initial and final radiographs, with cephalometric superimpositions.

recommended some distal inclination to the crown of these molars, similar to the tip-back bends made on anchorage on Tweed-Merrifield technique. A six-degree distal inclination on the molars was suggested to compensate this tendency.[20] By doing this, notice that the aligner will tend to disadapt on the mesial cusp, so it is important to increase the retention of the aligner by adding an attachment on the mesial cusp or bonding buttons to use vertical elastics. These precautions will make it more likely that the aligner keeps the tracking the whole movement.

If we consider the bow arch effects of the aligners and the root volume of the molars, the chance of having heavy side effects of lingual inclination and extrusion of the incisors is even bigger. To compensate for that, buccal crown inclination of 10 degrees must be added as an overcorrection, as well as a marked intrusion on the incisors.[20] In case it is necessary to compensate exclusively by adding buccal inclination, if, for some reason it is not possible to add intrusion on incisors, it will be made by adding pressure areas on the cervical buccal surface and on the incisal lingual surface. This force arrangement may cause the aligner to disadapt, so, to avoid that, it is suggested that a retention attachment is added at the buccal surface. It will prevent the aligner from disadapting and the movement will be better expressed.

It has been suggested that several movements need to be overcorrected when planning aligner treatments, considering that not every movement planned will be expressed to the full extent. Some movements have been verified to respond from 28 to 56%, with an average of 50% of what was planned.[21]

A good strategy related to overcorrections of some isolated movements, such as rotations or intrusions, is to ask that the movement is done normally during the aligner sequence, but the overcorrection to be done alone, at the end of the sequence. This way, if the initially planned movement is enough and the overcorrection is not needed, the professional can just skip these aligners and interrupt the treatment sooner. It is important though not to skip overcorrections in movements that tend to be unstable, with high risk of relapse, because it will be important for long term stability, even if the tooth respond well.

In cases of reciprocal space closure, the use of other auxiliary resources may be less critical if skeletal anchorage is associated with the aligners, but can still be very helpful in the prevention of side effects. Power arms, for example, can improve dramatically the root control and keep root parallelism during distalization of the canines and mesialization of molars. Despite moments created using vertical or optimized attachments to this end, it was clear on Figures 9 and 13 that these resources alone may not be enough. Vertical intermaxillary elastics on the medium segment of the arch on buttons bonded to the teeth may be a more predictable strategy to reduce the bow arch effect. The use of box elastics, even after the removal of the aligners, helps improve the final settling of the occlusion, compensating these inclination effects on molars with its extrusive force components caused by the elastics.

CONCLUSION

It is possible to treat complex cases with aligners. However, to obtain good aesthetic and functional results, it is necessary that the orthodontist:

» Select the patient's degree of motivation and collaborative profile.

» Invest a good amount of time in training, to better understand the characteristics of the appliances and the limitations of the technique.

» Prepare an individualized planning, having full awareness and control of the forces to be applied; anticipate and implement mechanisms to control their side effects.

» Consider the need to use auxiliary resources and overcorrections to address deficiencies in the aligner systems.

Digital planning and the use of aligners can be great allies for orthodontists, as well as can induce them to prescribe very unpredictable movements, since the virtual environment does not necessarily reflect *in vivo* conditions.

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— This section should be brief. The author must introduce the reader to the problem that is illustrated by the case report. This section should consist of one to three paragraphs, and it should begin with a general description of the problem to be illustrated, have a brief description of the literature and should end with a sentence that leads the reader into the purpose of the report.

Diagnosis and etiology
— The author should describe the dental and skeletal diagnosis. It is important to focus on the uniqueness or abnormality of the case and not on the normal findings. Anamnesis information, etiology of the malloclusion and any other information that would interfere with the treatment plan should be described. Preteatment radiographs and complete records are needed (models should be used if the intraoral radiographs can't portrait the clinical case and authors may be asked to submit pictures of the dental casts at the discretion of the editor). The author should refer to specific cephalometric measurements if necessary, and refer the reader to radiographs and photographs.

Treatment objectives
— The list of problems itemized in the diagnosis and etiology section should match a list of specific treatment objectives to solve each of these problems. The treatment objectives should include references to the maxilla, mandible, maxillary dentition, mandibular dentition, occlusion, and facial esthetics. The objectives should include goals for those.

Treatment alternatives
— The author must refer to all possible and reasonable treatment plans and describe the advantages and disadvantages of each alternative. The alternative chosen should be also described.

Treatment progress
— The author must describe the treatment for the patient thoroughly. Types of appliances, prescription, length of treatment, interaction with other aspects of dentistry, and special decisions that were made during treatment should be included.

Treatment results
— In this section the author should describe the results of orthodontic treatment. Final records must be presented in the same manner initial records were presented. In growing patients, total and partial superimposition are needed (Björk's method is suggested), while only a total superimposition for non-growing patients. It is important that the objectives and aim of the clinical case presentation are supported by the results. Conventional cephalometric measurements should be used, along with any specific measurement as long as they pertain to the objective of the clinical cases. It is suggested that the cephalometrics taken per each phase should not exceed 15 measurements

Discussion
— This section must discuss the uniqueness of this case report unique, how they relate to the decisions made by the author, and finally, how the treatment relates to the published literature on the topic. The discussion must contain references to the literature. The discussion should focus on the points that made the case report or the treatment of the patient unique. Each point is discussed in a separate paragraph with reference to the patient's treatment and the appropriate literature.

Summary and conclusions
— The author should write one paragraph that summarizes what was learned from this specific case

References
— The format for this section is the same as that found in scientific articles of the DPJO

1. Registration of clinical trials

Clinical trials are among the best evidence for clinical decision making. To be considered a clinical trial a research project must involve patients and be prospective. Such patients must be subjected to clinical or drug intervention with the purpose of comparing cause and effect between the groups under study and, potentially, the intervention should somehow exert an impact on the health of those involved.

According to the World Health Organization (WHO), clinical trials and randomized controlled clinical trials should be reported and registered in advance.

Registration of these trials has been proposed in order to (a) identify all clinical trials underway and their results, since not all are published in scientific journals; (b) preserve the health of individuals who join the study as patients and (c) boost communication and cooperation between research institutions and other stakeholders from society at large interested in a particular subject. Additionally, registration helps to expose the gaps in existing knowledge in different areas as well as disclose the trends and experts in a given field of study.

In acknowledging the importance of these initiatives and so that Latin American and Caribbean journals may comply with international recommendations and standards, BIREME recommends that the editors of scientific health journals indexed in the Scientific Electronic Library Online (SciELO) and LILACS (Latin American and Caribbean Center on Health Sciences) make public these requirements and their context. Similarly to MEDLINE, specific fields have been included in LILACS and SciELO for clinical trial registration numbers of articles published in health journals.

At the same time, the International Committee of Medical Journal Editors (ICMJE) has suggested that editors of scientific journals require authors to produce a registration number at the time of paper submission. Registration of clinical trials can be performed in one of the Clinical Trial Registers validated by WHO and ICMJE whose addresses are available at the ICMJE website. To be validated, the Clinical Trial Registers must follow a set of criteria established by WHO.

2. Portal for promoting and registering clinical trials

With the purpose of providing greater visibility to validated Clinical Trial Registers, WHO launched its Clinical Trial Search Portal (http://www.who.int/ictrp/network/en/index.html), an interface that allows simultaneous searches in a number of databases. Searches on this portal can be carried out by entering words, clinical trial titles or identification number. The results show all existing clinical trials at different stages of implementation with links to their full description in the respective Primary Clinical Trials Register.

The quality of information available on this portal is guaranteed by the producers of the Clinical Trial Registers that form part of the network recently established by WHO, i.e., WHO Network of Collaborating Clinical Trial Registers. This network will enable interaction between the producers of the Clinical Trial Registers to define the best practices and quality control. Primary registration of clinical trials can be performed at the following websites: www.actr.org.au (Australian Clinical Trials Registry), www.clinicaltrials.gov and http://isrctn.org (International Standard Randomized Controlled Trial Number Register (ISRCTN). The creation of national registers is underway and, as far as possible, registered clinical trials will be forwarded to those recommended by WHO.

WHO proposes that as a minimum requirement the following information be registered for each trial. A unique identification number, date of trial registration, secondary identities, sources of funding and material support, the main sponsor, other sponsors, contact for public queries, contact for scientific queries, public title of the study, scientific title, countries of recruitment, health problems studied, interventions, inclusion and exclusion criteria, study type, date of the first volunteer recruitment, sample size goal, recruitment status and primary and secondary result measurements.

Currently, the Network of Collaborating Registers is organized in three categories:

» Primary Registers: Comply with the minimum requirements and contribute to the portal;

» Partner Registers: Comply with the minimum requirements but forward their data to the Portal only through a partnership with one of the Primary Registers;

» Potential Registers: Currently under validation by the Portal's Secretariat; do not as yet contribute to the Portal.

3. Dental Press Journal of Orthodontics - Statement and Notice

DENTAL PRESS JOURNAL OF ORTHODONTICS endorses the policies for clinical trial registration enforced by the World Health Organization - WHO (http://www.who.int/ictrp/en/) and the International Committee of Medical Journal Editors - ICMJE (# http://www.wame.org/wamestmt.htm#trialreg and http://www.icmje.org/clin_trialup.htm), recognizing the importance of these initiatives for the registration and international dissemination of information on international clinical trials on an open access basis. Thus, following the guidelines laid down by BIREME / PAHO / WHO for indexing journals in LILACS and SciELO, DENTAL PRESS JOURNAL OF ORTHODONTICS will only accept for publication articles on clinical research that have received an identification number from one of the Clinical Trial Registers, validated according to the criteria established by WHO and ICMJE, whose addresses are available at the ICMJE website http://www.icmje.org/about-icmje/faqs/clinical-trials-registration/. The identification number must be informed at the end of the abstract.

Consequently, authors are hereby recommended to register their clinical trials prior to trial implementation.

Yours sincerely,

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Incisor root length in individuals with and without anterior open bite: a comparative CBCT study

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DOI: *https://doi.org/10.1590/2177-6709.25.4.23.e1-7.onl*

Objective: This study aimed to compare the root length of maxillary and mandibular incisors between individuals with open bite *versus* matched individuals with adequate overbite.

Methods: This comparative, matched and retrospective study included 48 cone beam computed tomographies (CBCTs) obtained at a university radiological center. Scans belonged to 24 individuals with open bite (overbite $\leq$0 mm) and 24 individuals with adequate overbite (controls). Both groups were matched by age, sex, malocclusion classification and skeletal characteristics (ANB and FMA angles). Root length of each maxillary and mandibular incisor was measured in millimeters (mm) in a sagittal section from a perpendicular line to the enamel cement junction until the root apex (384 length measurements were made). The means of root length in both groups were compared using *t*-tests. In addition, correlations between variables were evaluated with the Pearson correlation coefficient ($\alpha = 0.05$).

Results: In both groups, the root length of the upper central incisors was approximately 12 mm and the root length of the maxillary lateral incisors was approximately 13 mm ($p > 0.05$). Likewise, the root length of lower central incisors in both groups measured approximately 12 mm ($p > 0.05$). However, the mandibular lateral incisor roots of open bite patients were significantly longer than in the normal overbite patients (approximately 1 mm, $p = 0.012$ right side, $p = 0.001$ left side).

Conclusions: Root length of maxillary incisors and central mandibular incisor is similar in individuals with or without open bite, but the mandibular lateral incisor roots in open bite patients were significantly longer than in the normal overbite patients.

Keywords: Open bite. Incisor. Root length. Cone-beam computed tomography.

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INTRODUCTION

It has been reported that individuals with open bite have greater incisor dentoalveolar height, compared with balanced facial pattern subjects.[1,2] Based on the increased vertical skeletal and dentoalveolar dimensions that open bite individuals present,[1,3-7] it could be speculated that the root lengths of anterior teeth would be greater in open bite individuals, when compared to those without open bite.

Contrarily, some authors found shorter maxillary central incisor length in open bite patients compared to controls without open bite,[8] or with deep bite[9], based on lateral cephalogram evaluation. However, the root length was not directly measured.[8,9] In addition, only two studies that evaluated dental root length in panoramic radiographs[10] and root area in CBCT[11] concluded that patients with open bite, especially those with a high mandibular plane angle, have shorter dental roots and smaller root areas of the maxillary incisors, when compared to individuals with normal overbite. These studies mention that their findings may be related to the loss of occlusal contact in the anterior teeth. It is important to emphasize that open bite individuals present counterclockwise rotation of the palatal plane and clockwise rotation of the mandibular plane,[5,12-14] increasing the lack of contact between maxillary and mandibular incisors.[10] However, a clear relationship between open bite and the presence of shorter or longer roots is not yet established, since studies that evaluate, specifically, the root length of individuals with open bite have been rarely reported. Thus, these results should be evaluated in other samples for better consistency.[15]

Therefore, the purpose of this study was to compare the root length of maxillary and mandibular incisors between individuals with open bite *versus* matched individuals with adequate overbite.

MATERIAL AND METHODS

This comparative and retrospective study was approved by the Ethics and Research Committee of the *Universidad Científica del Sur*, Lima/Peru (# 00021). The sample involved 48 CBCTs obtained from the files of a radiologic center at the *Universidad Científica del Sur*, of patients who underwent orthodontic-surgical treatment planning.[16] The CBCTs were divided into two groups: Group 1, consisting of 24 scans of individuals with anterior open bite; and Group 2, consisting of 24 scans of individuals with an adequate overbite (controls). The patients were matched by age, sex, malocclusion classification and skeletal characteristics (ANB and Frankfort mandibular plane-FMA angles).

Sample size was calculated considering an 80% of test power at a confidence level of 95%, with a mean intergroup difference to be detected of 2mm in the root length of maxillary central incisors, with a standard deviation of 1.60mm, as previously reported.[10] Although the required sample was 10 individuals per group, 24 subjects per group were included.

The inclusion criteria of the anterior open bite group included individuals with overbite of 0mm or less (negative), mandibular plane angle defined by FMA angle >26° for both sexes, age range from 20 to 40 years, with all permanent teeth (excluding third molars), with Class I, II or III malocclusions. The control group included individuals with overbite from 1 to 4 mm, and with the same criteria of the open bite group. In both groups, individuals with syndromic craniofacial deformations, maxillofacial surgeries, history of previous orthodontic or orthopedic treatment, incisors with endodontic treatments, impacted canines or tooth loss prior to CBCT were excluded.

CBCT scans of all patients were taken using a tomographic equipment model Picasso Master 3D (Vatech Co., Ltd., Hwaseong, South Korea), set at 8mA, 90KVp, isotropic voxel size of 0.3mm and exposure time of 20 seconds. Each field of view mode was of 20 x 19cm. All variables were measured in the RealScan software (version 2.0, PointNix Co., Ltd., South Korea).

The overbite was measured, using the volumetric reconstruction (VR), as the distance in mm between the incisal edges of the maxillary and mandibular incisors, perpendicular to the occlusal plane. Malocclusion classification was evaluated in the dental casts.

Lateral cephalograms generated from CBCT were used to measure the cephalometric variables.[17] Skeletal relationship was evaluated with the ANB angle and the facial pattern with the FMA angle.

The root length of each central and lateral maxillary and mandibular incisors was measured in millimeters. To obtain the tomographic cuts, the longitudinal axis of each incisor was located in the axial,

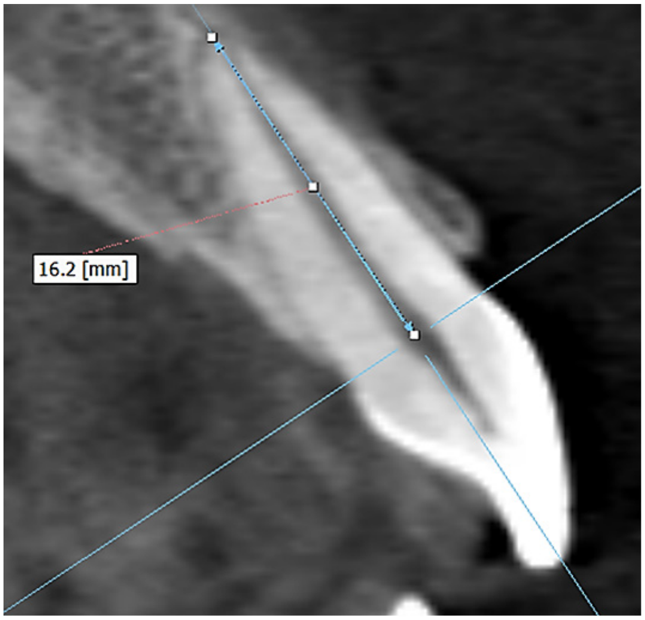

Figure 1 - Root length measurement of maxillary incisor in the sagittal section.

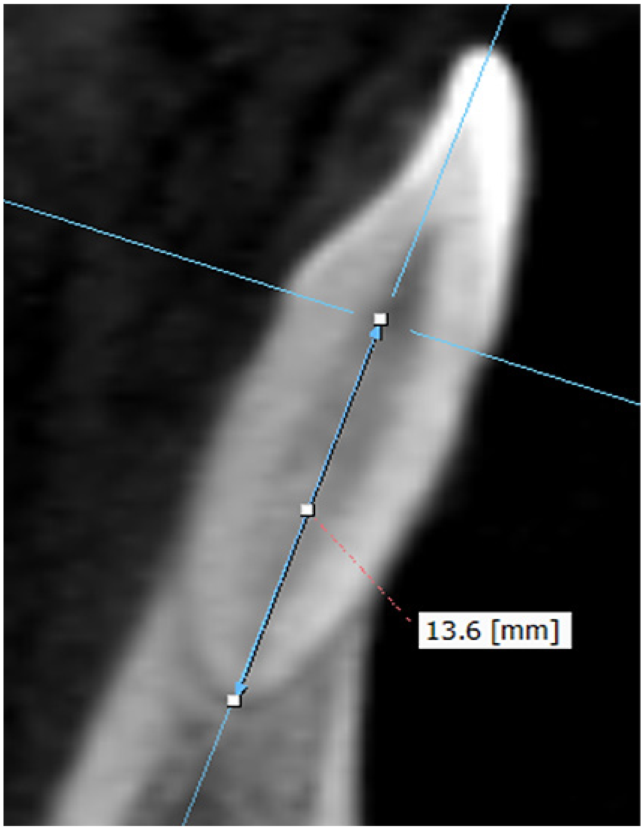

Figure 2 - Root length measurement of mandibular incisor in the sagittal section.

sagittal and coronal views. Then, in the sagittal section the root length was measured on the same longitudinal axis, from a perpendicular projection of the labial cement-enamel junction up to the vertex of the root apex of each incisor (Figs 1 and 2).

Error study

All measurements were made twice, at two different times, separated by a one-month interval, by two different examiners. The values obtained were evaluated through the intraclass correlation coefficient (ICC), to determine the intraexaminer and interexaminers concordance. Values greater than 0.85 (CI to 95%, 0.70-0.98) were obtained. Random errors were calculated according to Dahlberg's formula,[18] giving values smaller than 1mm in all quantitative variables.

Statistical analysis

All statistical analyses were performed using SPSS software for Windows (version 19.0; IBM, Armonk, NY). Normal distribution was tested and confirmed with the Shapiro-Wilk tests. Intergroup comparisons regarding sex and malocclusion distributions were performed with Chi-square tests. Intergroup comparisons regarding age, overbite, ANB and FMA angles and root lengths were performed with *t*-test. Finally, correlations between overbite and root lengths were evaluated with the Pearson correlation coefficient. The significance level was set at $p < 0.05$.

RESULTS

The groups were comparable regarding sex, malocclusion classification, age, ANB and FMA angles (Tables 1 and 2). The control group presented statistically significant greater overbite than the open bite group (Table 2).

Root lengths ranged from 12.29 mm to 13.20 mm for the maxillary incisors, and did not show significant intergroup differences (Table 2).

For the mandibular central incisors, the root lengths ranged from 11.49 mm to 11.71 mm, and only the root lengths of the open bite mandibular lateral incisors were significantly greater than the normal overbite group.

There were significant inverse correlations between overbite and the root lengths of the mandibular lateral incisors, but with low to moderate strengths (Table 3).

Table 1 - Distribution of both groups according to sex and malocclusion.

Variable	Values	Control group	Open bite group	Total	*p*
Sex	Male	12	12	24	1.000
	Female	12	12	24	
Angle malocclusion	Class I	6	6	12	1.000
	Class II	8	8	16	
	Class III	10	10	20	

Chi-square test.

Table 2 - Group comparability regarding the initial characteristics and intergroup comparisons of root lengths.

Measurements	Control group (n=24)		Open bite group (n=24)		Mean difference	Lower Limit CI to 95%	Upper Limit CI to 95%	*p*
	Mean	SD	Mean	SD				
Initial characteristics								
Age	33.80	9.07	30.89	7.40	2.91	-3.24	8.57	0.343
Overbite	2.71	1.49	-2.65	2.26	5.36	4.13	6.58	<0.001*
ANB Angle								
Class I	1.31	0.21	1.23	0.77	0.08	-2.35	2.50	0.907
Class II	6.20	1.22	6.42	1.49	-0.22	-1.34	1.45	0.857
Class III	-3.37	2.02	-2.35	1.85	-1.01	-2.84	0.80	0.257
FMA	28.10	2.43	30.15	4.34	-2.05	-4.35	2.50	0.079
Root lengths								
Maxillary right central incisor	12.94	1.24	12.29	1.72	0.65	-0.30	1.61	0.178
Maxillary left central incisor	12.81	0.98	12.50	2.26	0.31	-0.81	1.42	0.583
Maxillary right lateral incisor	13.06	1.31	12.96	1.79	0.10	-0.91	1.10	0.849
Maxillary left lateral incisor	13.12	0.80	13.20	1.65	-0.08	-0.90	0.75	0.846
Mandibular right central incisor	11.71	0.62	11.71	1.43	0.00	-0.70	0.70	1.000
Mandibular left central incisor	11.82	0.75	11.49	1.38	0.33	-0.38	1.04	0.353
Mandibular right lateral incisor	11.79	0.77	12.87	1.66	-1.08	-1.92	-0.25	0.012*
Mandibular left lateral incisor	11.70	0.98	12.07	1.41	-0.37	-2.16	-0.59	0.001*

*Statistically significant at $p<0.05$ (t-test).

Table 3 - Correlation values between the overbite and the root length of maxillary (Mx.) and mandibular (Md.) incisors.

Pearson correlation		Mx. right central incisor	Mx. left central incisor	Mx. right lateral incisor	Mx. left lateral incisor	Md. right central incisor	Md. left central incisor	Md. right lateral incisor	Md. left lateral incisor
Overbite	R	0.278	0.260	0.010	-0.140	-0.069	-0.048	-0.345	-0.490
	P	0.176	0.105	0.949	0.390	0.671	0.771	0.029*	0.001*

*Statistically significant at $p<0.05$.

DISCUSSION

A perfect similarity of the biological and physical characteristics of the individuals in both groups was difficult to achieve due to the great individual variability of the participants. Nevertheless, this is one of the few studies that directly evaluate root lengths in subjects with and without open bite using CBCT scans.

Some authors compared the dentoalveolar height of incisors with respect to the palatal plane, between subjects with and without open bite, finding that individuals with open bite have greater dentoalveolar height of incisors.[1,2] However, these results only identify that the incisors in open bite subjects have greater dentoalveolar height, but they did not evaluate their root lengths. In this way, Harries and Butler[9] found, on lateral radiographs, that the length of permanent maxillary central incisors was significantly shorter in adolescents with open bite than matched adolescents with deep bite before orthodontic treatment.

There are a few investigations that have compared the incisor or root lengths between individuals with and without open bite. A first study was carried out by Arntsen et al.[8] on lateral radiographs and evaluated the entire incisor length, including the crown and the root. They concluded that the length of the upper incisors was smaller in open bite individuals when compared to controls without open bite. Based on these results, it could be thought that if the maxillary incisor length is shorter in open bite individuals, the same may be expected for the root size. However, this is a speculation. In addition, lateral radiographs have the disadvantage of presenting image superimposition of both central incisors, thus the length evaluation of any incisor requires a very good calibration.

Subsequently, Uehara et al.[10] through panoramic radiographs, compared the root-crown ratio and root length between individuals with open bite and controls with normal overbite. They found that open bite individuals had smaller crown-root ratio and root length from the incisors to premolars in maxillary and mandibular teeth, when compared to individuals with normal overbite. They attributed this characteristic to the loss of occlusal contact, arguing that in the lack of occlusal contact or hypofunction, there could be some atrophic changes in the periodontal ligament that could influence root length. They stated the limitations of using panoramic radiographs and suggested further research using CBCT.

A recent study using CBCT reported that root surface areas of maxillary incisors are smaller in open bite individuals, when compared to controls without open bite.[11] They attributed their results to the occlusal hypofunction mentioned above, and speculated that some abnormal pressure from a tongue thrusting habit could cause root resorption of these teeth. Nevertheless, their sample size and age range were smaller than in the present study, and it may have influenced their results. In addition, it should be considered that length and area measurements are different. One might find smaller area in a narrow and longer root or a greater area in a wide and shorter root. Thus, area and length measurements should be independently and carefully assessed.

Contrary to the findings of these studies, it could be thought that if open bite patients present greater vertical dimensions and dentoalveolar heights than subjects with normal overbite,[1,3-6] the presence of similar or even greater dental tooth size and consequently greater root length could be expected. However, the results of this study showed no significant difference in root length of maxillary incisors between subjects with and without open bite (Table 2). This may be explained because the groups did not show significant difference regarding the vertical skeletal pattern. In groups with significant vertical skeletal differences, this scenario may change, and this should be evaluated in future research.

Since no significant differences were found for the maxillary incisors, the same results would be expected for the mandibular incisors. However, significant differences were found in the lateral incisors, showing that individuals with open bite have greater root length, ranging from 0.37mm to 1mm, approximately, when compared to the control individuals (Table 2). In addition, significant inverse correlations were found between root length of mandibular lateral incisors and overbite; however, they presented low to moderate strength, which is not clinically relevant (Table 3). Although these results are in accordance with the speculations of greater root length in open bite subjects, these differences lack clinical relevance. Again, further studies comparing extreme vertical malocclusions should be performed to confirm these results.

If incisors with short roots are a typical characteristic of individuals with open bite malocclusion, this should be a common finding in the different published studies involving different samples. However, the lack of articles that evaluate this association, i.e., lack of consistency (previous articles supporting this relationship),[15] beyond those mentioned above, make it difficult to justify this conclusion. Therefore, future studies are necessary to clarify this causality relationship. Furthermore, for the existence of a cause-effect relationship between two variables (i.e., the existence of short roots and the presence of an open bite), certain specific characteristics should be necessary to eliminate any type of coincidence. Thus, the concept of temporality (firstly, existence of the independent variable; and secondly, presence of the outcome variable) is essential, but this could only be evaluated and demonstrated through follow-up studies ensuring the absence of the outcome variable at the beginning of the study. Plausibility (biological explanation of this relationship) is another concept that should be clear to ensure this relationship, that is defined as the biological explanation why individuals with an open bite could have short roots. Likewise, the strength of association, the biological gradient and coherence are other factors that a causal relationship should also fulfill.[15] The present study, by its own design, did not seek to evaluate a true causality relationship, but sought to determine whether root length presents significant differences between comparable individuals with and without open bite, information that could be applied in clinical practice.

Consequently, associating the present results with the controversy about greater root resorption after orthodontic treatment in open bite patients,[19-21] the orthodontist could understand that treatment planning in individuals with and without open bite should have similar considerations regarding the initial condition of root length. In both cases, factors that could cause moderate root resorption of incisors should be similarly avoided.

CONCLUSIONS

Root length of maxillary incisors and mandibular central incisors is similar in individuals with or without open bite, but root lengths of mandibular lateral incisors in the open bite group were significantly greater than in the normal overbite group.

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