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Original Articles

Online Articles

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Covid 19 pandemic unveiling the opportunities and challenges in orthodontic training

Flavia **Artese**[1]

The COVID-19 pandemic disrupted every single aspect of society, with most professions having to rapidly adapt to the new circumstances, and these were affected at different levels due to specific demands of contamination control. In the USA, OSHA (Occupational Safety and Health Administration) early on classified Dentistry as a 'very high-risk' category, having doctors, staff and patients themselves exposed to aerosol-generating procedures. Clearly, this contamination risk not only impacted orthodontic practice, but also orthodontic training.

Guidelines for clinical activities in dentistry were established[1] and, in general, measures had the purpose of avoiding transmission routes through droplets or direct contact. Changes in practice were drastic, and affected the entire clinical setting, from the front desk all the way to the surgery. And these guidelines obviously had to be carried over to clinical orthodontic training.

Face to face education as a whole was halted, since social distancing was mandatory for reducing contamination. The conventional teaching model of a teacher and a classroom full of students was most probably the first thing to stop in most countries. E-learning became the main option, and many dental schools had to shift to this teaching model with very little or no practice at all in distance learning. Orthodontic education was no different, and very little information or recommended guidelines were available to ensure the fulfillment of its curriculum.

In collaborative efforts, specialty organizations, such as the Angle East and the Angle Society of Europe, put together 8 weeks' worth of one-hour seminars, offered daily to orthodontic graduate students. Over 300 programs worldwide had free enrollment and their residents were exposed to a wealth of knowledge not attainable in different circumstances. Individual efforts were also evident, such as Kevin O'Brien's paper discussions, to mention a few of the several others available on different electronic media.

Nevertheless, dental education faces serious challenges, as two recent papers point out these aspects in the United States,[2,3] the data can be extrapolated to other countries. Most dental schools have to deal with its multiple functions in society, which are not limited to teaching, but also include patient treatment and research. This is not different in orthodontic graduate training, since orthodontics, as most dental specialties, is of an operatory nature and a key part of education is performed in the surgeries or clinics.

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The Association for Dental Education in Europe (ADEE), with the aim of getting the picture of the first response of European dental schools to the COVID-19, sent out an electronic survey to 153 dental schools.[4] The responses were collected from March 25th to April 5th, 2020 and covered five main areas: clinical activities, non-clinical teaching, assessment, emotional support and future implications. Results showed that non-clinical teaching was performed online in 90% of the schools. Evaluations were postponed in 72% of the schools, since clinical requirements could not be performed. The well-being of staff and students were managed centrally by 50% of the schools, with dedicated web pages and online meetings. Finally, 90% of the schools believed that COVID-19 crisis will change permanently dental education.

The greatest challenge is that orthodontic education has a high need of clinical activities. Despite the technology advances that include robots and electronic typodonts, these are not portable resources and cannot be used to replace hands-on clinical training. Also, the patient-doctor relationship can only be learnt in a physical clinical setting. To be able to offer clinical training at this time, modifications in clinical settings will be needed, demanding large financial investments; and as clinical activity will be slower, involving less people, this will be the most significant obstacle in offering the orthodontic resident the fulfillment of his/her training with no loss in quality.

Research has never been so valued by society in searching for a vaccine or medication for this disease.[5] However, it has also affected orthodontic research, especially those performed in a clinical setting. The research financing and the deadlines of research grants will probably not be extended, as well as the completion of these projects as orthodontic graduation requirements. Needless to say the impact on future research grants, as well as the financial impact on universities as a whole, since most of them are dependent on tuition fees.

Despite the enthusiasm with the fact that orthodontic residents have never been exposed to such amount of theoretical information during the lockdown period, and the value that e-learning almost instantly received due to the pandemic, some other challenges lie ahead of us. Educators involved in orthodontic training have to be very careful in respect to changes in teaching resources and dynamics. Even though some aspects of teaching can and will be adequately substituted by online lecturing, treatment skills are yet to be developed and performed on patients, which is not only about technique, but understanding of patient-doctor relationship. This pandemic has come for a definite change, but we have to be careful in offering substitutes to teaching, so as not to inflict on quality of learning. I believe a completely new demand of research on orthodontic education is ahead of us, so that these changes will also be based on evidence, rather than on the urgency of graduating our current students.

May the excellence in quality of orthodontic training prevail.

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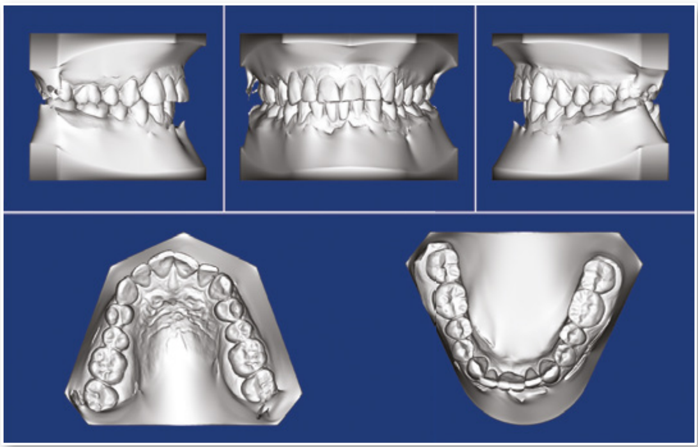

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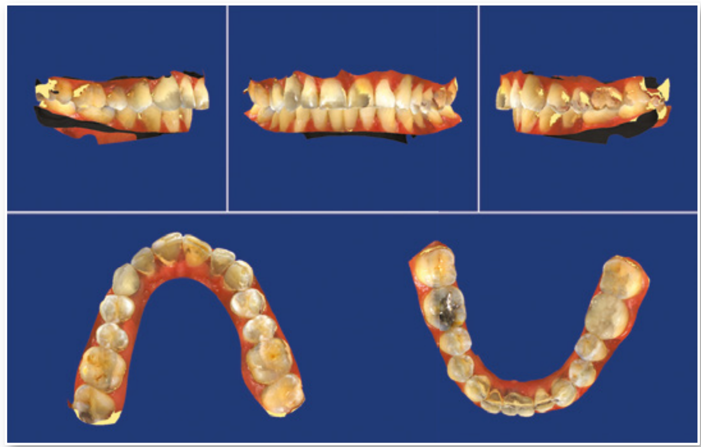

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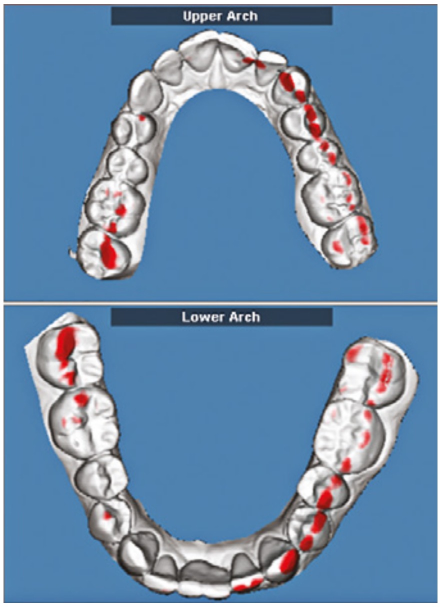

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Matheus Melo **Pithon**[1,2]

MICRO-OSTEOPERFORATION DOES NOT ACCELERATE ORTHODONTIC MOVEMENT

Fast-acting orthodontic treatments are desired by both patients and orthodontists. In recent years, a multitude of methods and products have been developed to this end. Osteoperforations are currently in fashion, mainly because the industry was able to take this old idea to sell customized osteoperforators. It is not the product that will make the difference, but rather the procedure. Thus, Iranian researchers developed a study[1] aimed at assessing the effect of micro-osteoperforation (MOP), made with mini-implants, over a period of three months, and determining the influence of the number of perforations on the canine retraction rate. In addition to assessing the amount of pain and discomfort caused by the method, a controlled, randomized triple-blind clinical trial was carried out with twenty-eight patients, ranging in age from 16.3 to 35.2 years, who needed fixed orthodontic treatment. The patients were randomly assigned to groups MOP1 and MOP2. In each patient, one side of the mouth acted as a control that did not receive MOPs. Four months after extraction of the first premolars, patients in the MOP1 group received 3 MOPs in the vestibular of alveolar bone, on the experimental side, to accelerate canine retraction, while patients in the MOP2 group received three vestibular MOPs and three palatal MOPs on the experimental side (Fig 1). The amount of canine retraction was measured every 28 days, at three time intervals. Pain perception was also assessed, both on the day of the MOP procedure and subsequently at 24 h. The results of the study revealed that MOPs were effective in accelerating tooth movement over a period of three months; however, the increase in tooth movement after MOP application was not clinically significant. The results also revealed that there was no increase in the level of pain or discomfort with MOP.

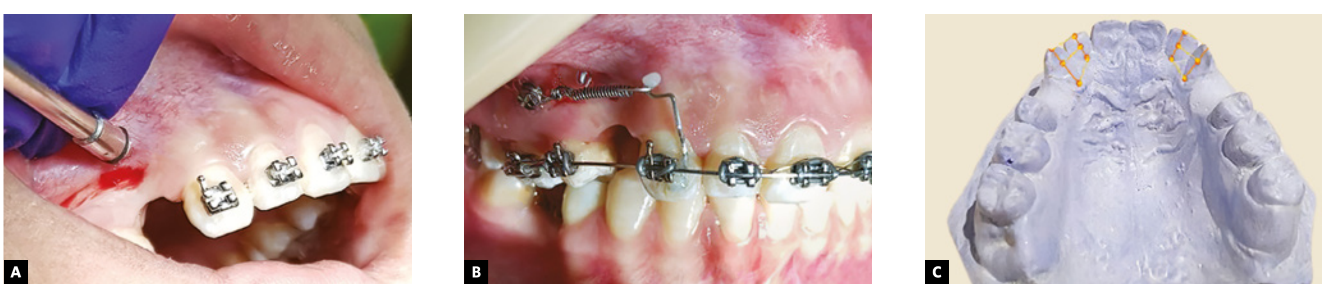

Figure 1 - A) MOP procedure. B) Nickel-titanium spring stretched between the force arm and the mini-implant. C) Canine retraction was calculated in the models by measuring the distance between two lines drawn at the midline of the lateral incisor and canine at three points — the incisal, middle and cervical thirds of the crowns. Source: Babanouri et al.[1], 2020.

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THERE IS NO GOOD SCIENTIFIC EVIDENCE TO PROVE THE LOW CYTOTOXICITY OF AND RELEASE OF MONOMERS FROM THERMOPLASTIC DEVICES

The use of thermoplastic materials in orthodontics has being growing daily. Their use has been concentrated on the manufacture of aligners and retainers. Despite widespread popularity, there is no consensus regarding the safety of these materials when in contact with oral tissues. Recently, a group of Greek and Swiss researchers published a systematic review and meta-analysis,[2] aimed at collectively evaluating the existing evidence from clinical and laboratory studies, concerning whether thermoplastic devices are associated with estrogenic/cytotoxic effects or bisphenol-A (BPA) release and monomers. Eight electronic databases were searched. In total, 58 articles were initially identified, with five included in the qualitative synthesis and two of those contributing to the quantitative syntheses. Four were in-vitro studies, while one was randomized; all evaluated some type of aligner or orthodontic retainer. The results revealed that no cytotoxic effects of thermoplastic devices could be confirmed based on the available evidence. Regarding the release of monomers or BPA, the evidence remained ambiguous. The authors emphasized that, due to the inconsistency of the available evidence, new laboratory and clinical studies with higher-quality methodologies are necessary.

INDIVIDUALS WITH AGENESIS OF THE UPPER LATERAL INCISOR HAVE AN INCREASED FREQUENCY OF CERVICAL ABNORMALITIES

A common problem in orthodontic clinic is the congenital absence of any dental element, also known as agenesis. The upper lateral incisors are teeth that are often absent. There is a chance that the agenesis of upper lateral incisors could be accompanied by other bodily changes such as cervical abnormalities. In the search for evidence to prove this hypothesis, Chinese researchers developed a study[3] that aimed to evaluate the association between the congenital absence of the upper lateral incisor (MLI) with fusions of the cervical vertebral body, posterior arch deficiency and both anomalies. The study involved 64 individuals with agenesis of the upper lateral incisor (24 men and 40 women with a mean age of 16 ± 4.5 years). Two hundred and fifty-six individuals (87 men and 169 women, with an average age of 18.1 ± 3.2 years) were assigned to the control group. The results revealed that in the group with lateral agenesis, 53.7% revealed fusion of the cervical spine, 11.1% indicated posterior arch deficiency and 9.3% showed fusion of the cervical spine with posterior arch deficiency. The morphological deviations of the cervical spine showed significant associations with the congenital absence of an upper lateral incisor, compared to the control group ($p < 0.001$). Concluding that the individuals with MLI tend to have an increased frequency of cervical anomaly.

THE USE OF MOUTHWASH DURING ORTHODONTIC TREATMENT CAN CHANGE THE COLOR OF TOOTH ENAMEL

Aesthetics are, without a doubt, the main motivating factor in the search for orthodontic correction. At the end of orthodontic treatment, aligned teeth with natural color and texture are desired. The use of a fixed orthodontic appliance favors bacterial accumulation, which, if not eliminated correctly and daily, can frustrate the final result, with a natural color and texture of the enamel potentially not being achieved. Mechanical methods, such as brushing and flossing, are considered the gold standard when addressing plaque removal; however, in orthodontic patients, these methods may not be sufficient, and may require the additional use of chemical methods in the form of mouthwashes. There is no consensus in the literature regarding the effect of different mouthwashes on the color of the enamel after orthodontic detachment, however. In search of an answer to this question, Turkish researchers developed an in-vitro study[4] that was aimed at evaluating the color changes in enamel surfaces after orthodontic bracket detachment, following the use of different mouthwashes. For this, a total of 100 human premolar teeth were used, which were randomly divided into 10 groups. The oral surfaces of each tooth were evaluated using a digital spectrophotometer. Following this, orthodontic brackets were bonded to the teeth. The rinses evaluated were Colgate Plax, Listerine Cool Mint, Klorhex and Tantum Verde. After removing the brackets, a final measurement of the enamel color was made. The results achieved with this study revealed that the use of mouthwashes during orthodontic treatment can cause visible changes in the color of the teeth. According to the authors, the Listerine Cool Mint proved to be the best mouthwash option, having a lesser effect on the color of the enamel.

THE RELEASE OF IONS BY ORTHODONTIC APPLIANCES DEPENDS ON THE WELDING METHOD

The oral environment favors the biodegradation of metallic materials, associated with corrosion, due to chemical, physical and biological changes. Corrosion releases metal ions, and the products resulting from these reactions can trigger adverse effects, such as hypersensitivity. Although an increase in metal ions is commonly detected after the installation of orthodontic appliances, the levels can be considered low. Even if the amount released is low, however, there is a possibility of biological effects on oral cells, since these devices remain in the oral cavity for an extended period of time. In searching for materials and processes that can promote a lower release of metals from orthodontic appliances, the science evolves. Recently, a study[5] was published in a well-respected international journal by Brazilian researchers whose proposal was to quantify the release of ions in the saliva of patients with lingual arches who received different welding methods when they were made. Sixty-four patients were divided into four groups: G1 (control), G2 (silver-soldered lingual arch), G3 (laser-welded lingual arch) and G4 (TIG-welded lingual arch). Saliva samples were collected at four different points, and analyzed for ion release over a period of 30 days. The results from this study revealed that, for most of the ions evaluated, there was no significant increase when comparing types of welding; however, in the TIG-welded lingual arches, there was a greater release of Ni ions.

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Orthodontics and Endodontics: clinical decision-making

Alberto **Consolaro**[1], Dario Augusto Oliveira **Miranda**[2], Renata Bianco **Consolaro**[3]

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Endodontically treated teeth may be moved, as endodontic treatment is not a contraindication for orthodontic treatment. Apical periodontal repair begins when the periapical or pulp lesion has completely resolved. This may happen immediately after treatment if the filling material causes little or no irritation of periapical tissues, and particularly if the material is fully contained within the canal. When it leaks, a foreign body granuloma forms and persists for some months or indefinitely, depending on the composition of the filling material. Materials containing calcium hydroxide with no resin components undergo phagocytosis and disappear in some months, as macrophages gradually remove them. Materials containing resins, silicone, ionomers, zinc oxide-eugenol, bioceramics or gutta-percha remain in the site and induce the formation of foreign body granulomas. Although this does not preclude tooth movement, patients should be followed up every three months using periapical images to control the position of the material in relation to the tooth apex. "Pseudo" overfilling may be avoided if permanent filling is delayed until the time when orthodontic treatment is completed.

Keywords: Orthodontics. Endodontics. Orthodontics-Endodontics. Tooth resorption.

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One of the issues that raises the most questions and uncertainties in the orthodontic and endodontic clinical practice is the time at which a tooth may be moved after the completion of an endodontic procedure. This study extrapolates experimental and clinical knowledge accumulated from studies and clinical cases[1-11], particularly as there are no specific data about it in the relevant literature.

CHARACTERISTICS OF ORTHODONTIC FORCES

Orthodontic forces, very differently from the forces of occlusion and dental trauma, are characteristically very light, dissipating and applied to tissues slowly. Even the orthodontic forces classified as heavy, severe or intense are lighter than those of dental and occlusal trauma. In summary (Fig 1), we may say that:

1. Occlusal forces are abrupt, have moderate intensity and short duration, but are very repetitive.
2. Forces of dental trauma, which are very intense, abrupt and have an extremely short duration, are highly damaging to periodontal and tooth tissues.
3. Orthodontic forces are not comparable with those of occlusal and dental trauma in all aspects and parameters. They are markedly lighter and dissipating, even though they might be called heavy or intense in an orthodontic context or environment.

ORTHODONTIC MOVEMENT IS PRODUCED BY THE PERIODONTAL LIGAMENT

Orthodontic forces applied to the periodontal ligament slightly compress vessels and induce metabolic cellular stress by hypoxia. This stress is added to the mechanical cell stress that results from cytoskeletal deformation. In case of cellular stress, cells and tissues preserve their normal morphology under light microscopy, as this is not a disease or a case of tissue disorganization, but, rather, a differentiated stage of normal tissue with greater metabolic activity. In everyday life, tissues alternate from homeostasis to stress when performing their functions.

Induction of cellular stress in the periodontal ligament by orthodontic forces promotes a greater release of mediators, particularly those associated with bone resorption, such as some cytokines and prostaglandins. The purpose of this tissue reaction is to enlarge the space for cells, which was reduced by periodontal tissue compression. As a result of that, teeth will be moved.

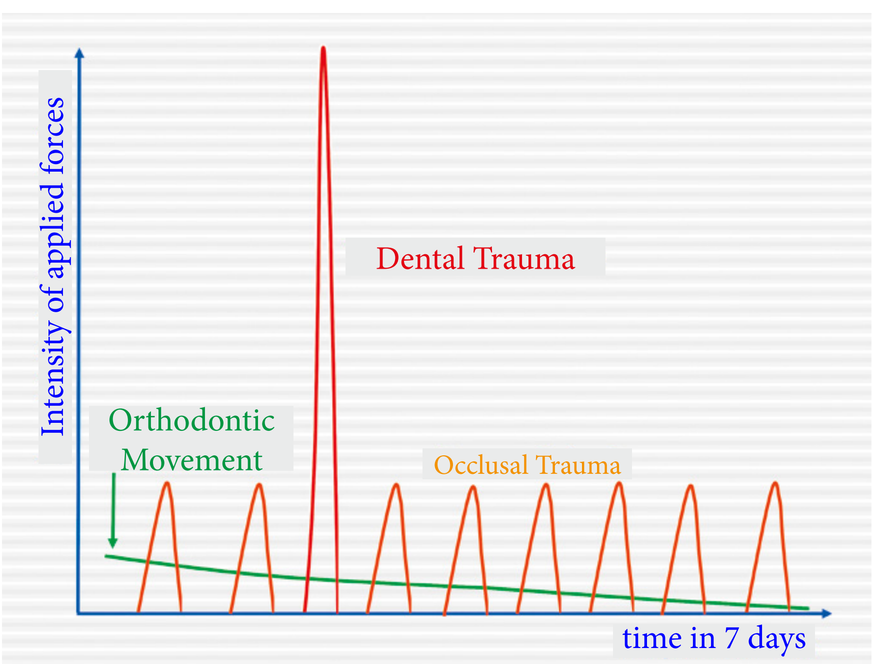

Figure 1 - Comparison of intensity and duration of forces applied in orthodontic movement, occlusal trauma and dental trauma. Intensity peaks and dental trauma duration should receive special attention. Tissue changes are very different in each case.

ENDODONTIC TREATMENT DOES NOT CHANGE THE SURROUNDING PERIODONTAL ENVIRONMENT

Cementum covers the root surface and closes dentinal tubules externally. Periodontal fibers are inserted into the cementum. Cementum and dentin physiologically separate the pulp from the periodontal ligament so that pulp structures and functions are fully preserved, as demonstrated in several experimental studies that evaluated ligament changes induced by orthodontic movement.

Periodontal tissues are microscopically normal when there are pulp changes or even necrosis. True endodontic-periodontic lesions are those that require both endodontic and periodontic treatment approaches, as they are lesions initially independent from each other, but that progress together along time. In other words, there is no efficient communication between the pulp chamber and the periodontium through the dentin and cementum wall, except in the case of lateral canals.

When a root canal is filled, the material used does not affect the antigenic composition of the dentin or the cementum (Fig 2). It is not possible to say whether endodontic treatment increases or decreases orthodontically induced resorption. There is no methodological basis for such claims and, therefore, teeth that have been adequately treated endodontically should be considered orthodontically normal teeth in clinical practice.

REPAIR OF PERIODONTIUM AND PERIAPICAL BONE LESIONS IN VITAL TOOTH PULPECTOMY

In the apical periodontal ligament continuous with the pulp at the margins of the cemental canal, repair in vital tooth pulpectomy begins as soon as filling is completed. In the interface between filling material and periodontal connective tissue, there is acute inflammation with edema and neutrophils. As there are no aggressors there, particularly no bacteria, this inflammation is reabsorbed and migrates to other areas (Fig 2) in 24-48 hours.

After this short time, macrophages are predominant and participate actively in repair and the return to normality, as they phagocytize cellular debris that may have been produced by instrumentation. Depending on the type of filling material used, neighboring cementoblasts may proliferate and gradually migrate into

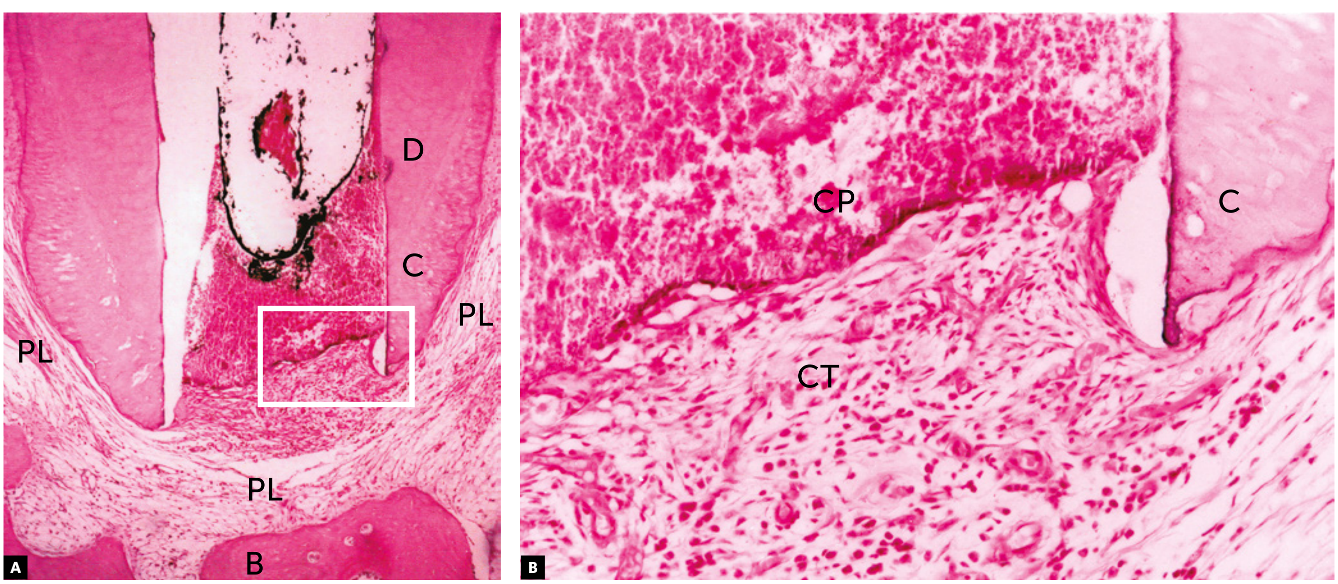

Figure 2 - Tissue reaction after canal filling with cement plug (CP) where periodontal tissue organizes as new connective tissue (CT); discrete signs of mononuclear inflammatory infiltrate and discrete angiogenesis remain. Lateral aspect of periodontal ligament (PL) is normal. (D=dentin, C=cementum, B=bone, PL= periodontal ligament – HE, 10X and 40X). (Source: Esberard[9], 1992).

the interface with adjacent tissues. There they may form cementoid material and result in the insertion of collagen fibers (Fig 3). This interface also has fibrous connective tissue without fiber insertions, but does not have any residual or persistent inflammation.

Macrophages can phagocytize, or try to phagocytize, some of the materials used for filling, gathering in their interfaces and forming a foreign body granuloma (Fig 4). If there are no microorganisms or sources of toxicity that may kill cells, this process remains there indefinitely, with no symptoms or detrimental effects to apical periodontal physiology.

REPAIR OF PERIODONTIUM AND APICAL BONE IN NON-VITAL TOOTH PULPECTOMY

After the endodontist eliminates the cause of pulp necrosis, particularly when it is induced by microbial agents, microbial products, such as enzymes and toxins, as well as lipopolysaccharides (LPS), are no longer expected to be found in periapical tissues. Endodontic treatments also eliminate microbial biofilm from the cemental canal and in the areas of root resorption of the cemental canal. This may result from mechanical action or the use of medications placed in the canal.

Periapical repair, which includes the bone and cementum, initiates as soon as aggressors are eliminated (Figs 3 and 5). Mean microbial survival time is 20 minutes for each generation. Therefore, between 24-48 hours, macrophages complete the phagocytosis of tissue and microbial residues. Exudate absorption is being completed by venous and lymphatic vessels. Therefore, cytotoxic microbial products, such as toxins, enzymes and LPS, are about to be fully eliminated.

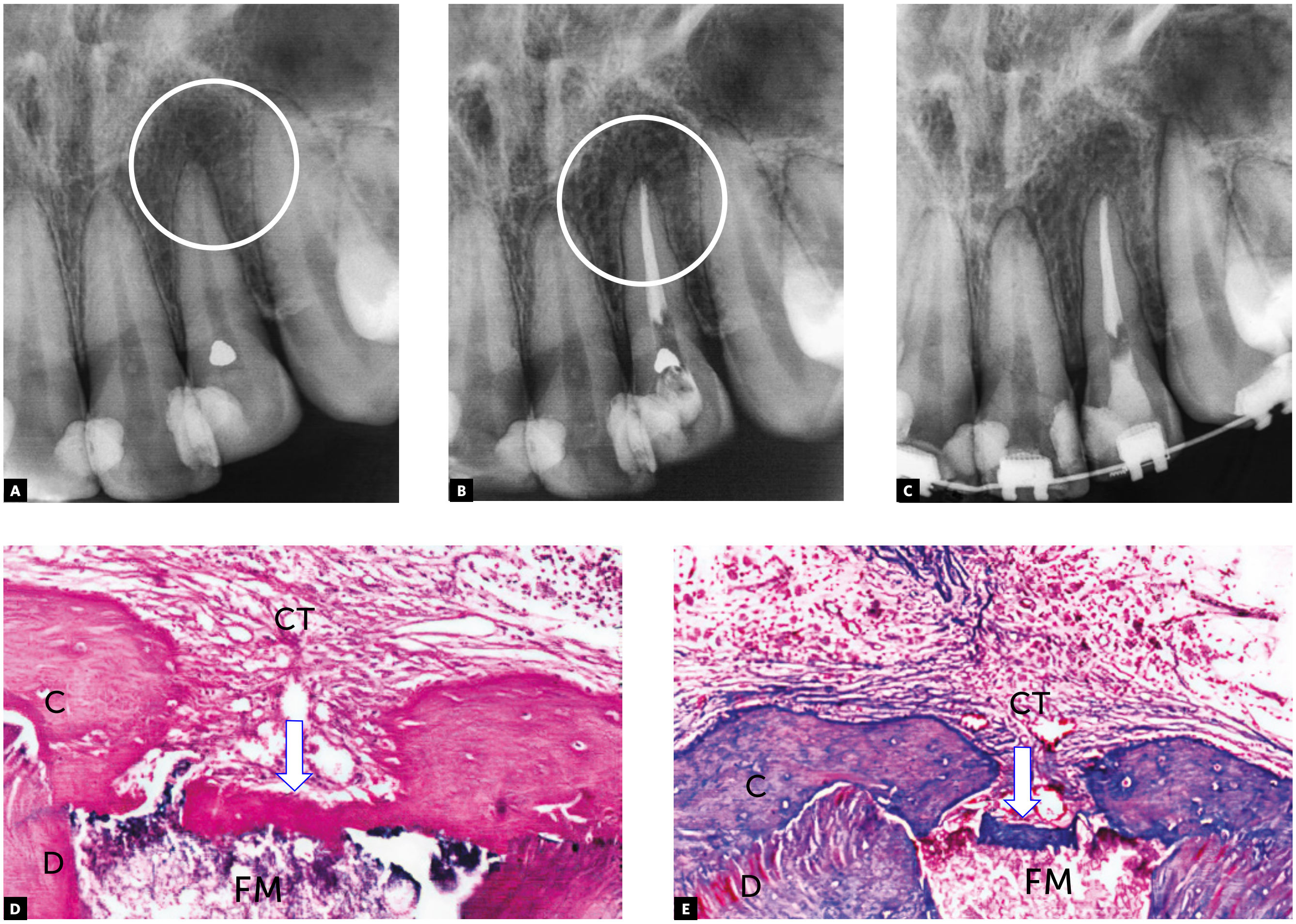

Figure 3 - Chronic periapical lesion compatible with incipient immunogenic periapical granuloma (circle) associated with pulp necrosis and canal contamination. Tooth was moved orthodontically soon after that. In some weeks, periodontal ligament was repaired and restored with new connective tissue (CT); cementoid tissue may form at interface (arrows) depending on type of filling material (FM). (D=dentin, C=cementum – HE and MT, 10X. (Source: Esberard[9], 1992).

However, this may not occur in all cases, as there may be failures even when the treatment is adequate. In some cases, microbial biofilm forms on the external surfaces of the apex, or even in more profound areas of external inflammatory resorptions.

REPAIR OF PERIODONTIUM AND APICAL BONE IN THE PULPECTOMY OF NON-VITAL TEETH WITH CHRONIC PERIAPICAL LESION

In addition to teeth with infected pulp necrosis still restricted to the root canal, there are also cases of infected pulp necrosis and chronic periapical lesions, particularly immunogenic periapical granulomas (Figs 3, 4 and 5). In practically all teeth with a chronic immunogenic periapical granuloma, external inflammatory resorptions are somehow intense, which makes it difficult to remove bacteria from within the dentinal tubules or from the surface irregularities in the area.

In teeth with chronic periapical lesions, microbial biofilm out of the cemental canal is more frequent and larger. There are also more free bacteria and microbial clusters inside the lesion. This complicates instrumentation and bacterial elimination by canal medications.

Such complication may explain the existence of a small percentage of these cases, which accounted for about 10% to 20% of a sample of teeth with pulp necrosis and chronic periapical lesions analyzed. In these cases, periapical lesions may persist and stabilize or grow along time, in which case they require endodontic retreatment or surgery. There will be no repair because of the persistence of aggressors, that is, bacteria and their products, particularly in microbial biofilm.

REPAIR OF PERIODONTIUM AND PERIAPICAL BONE IN ASEPTIC PULP NECROSIS

No microorganisms are involved in aseptic pulp necrosis (Fig. 6), except when this necrosis lasts longer than one year, in which case bacteria may reach that site via blood or anachoresis.

Adequate endodontic treatment of these cases usually leads to periapical and bone repair similar to that found in cases of vital tooth pulpectomy.

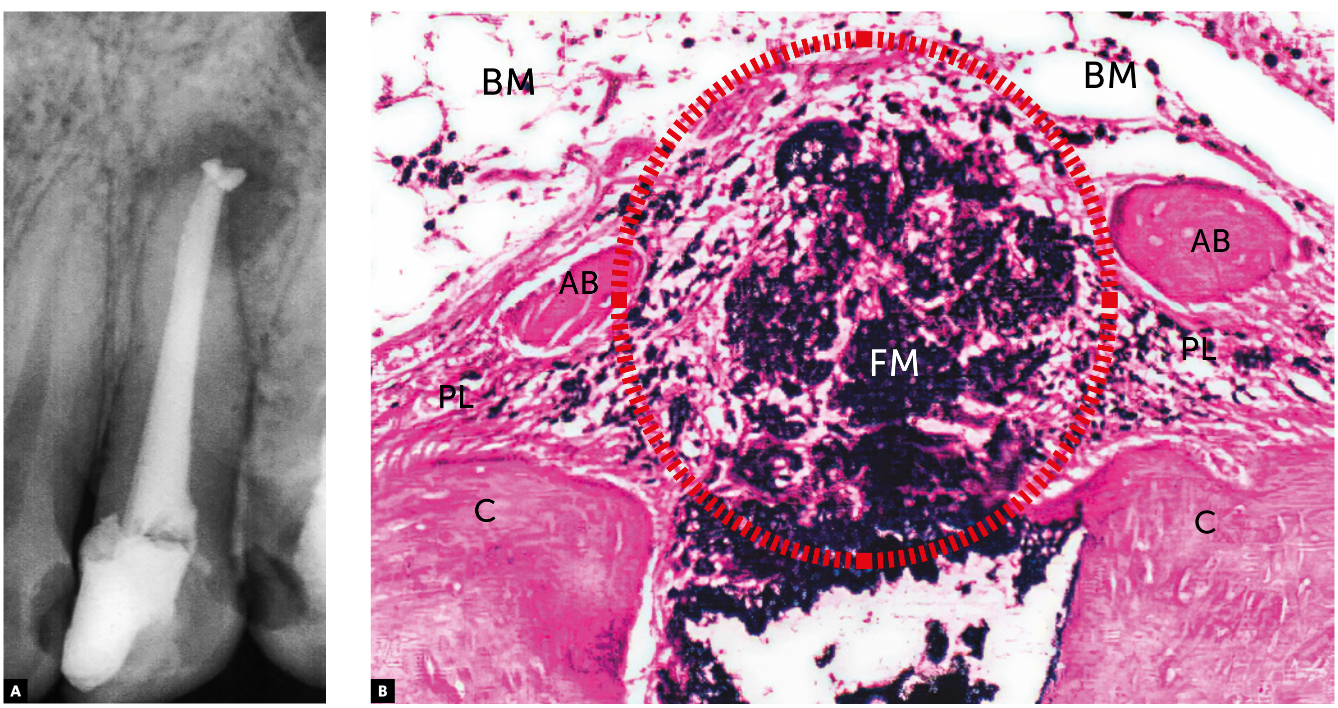

Figure 4 - Chronic periapical lesion compatible with immunogenic periapical granuloma; during treatment, filling material (FM) leaked, which is seen microscopically as dark dots and clusters with macrophages around it and forming a periapical foreign body granuloma (circle). (D=dentin, C=cementum, AB=alveolar bone, BM=bone marrow, PL = periodontal ligament – HE, 10X. (Source: Leonardo[10], 1992).

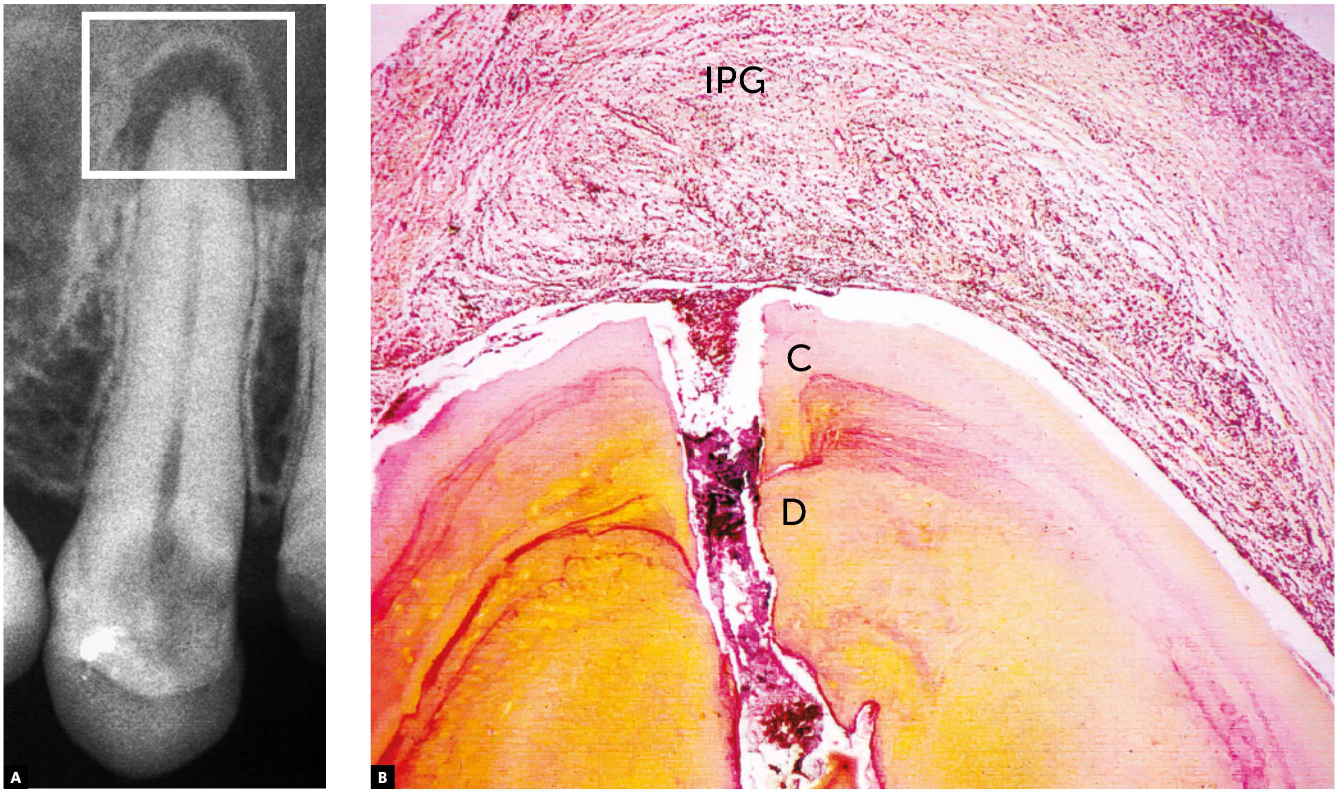

Figure 5 - Chronic periapical lesion compatible with incipient immunogenic periapical granuloma (IPG) associated with pulp necrosis and canal contamination, as seen microscopically in **B**. (D=dentin, C=cementum – BB, 10X).

After adequate root filling, a rapid acute inflammatory response initiates in 24-48 hours, soon leading to repair, because the main aggressor was in the products of aseptic pulp necrosis, which are considerably less aggressive to tissues and are previously eliminated.

ORTHODONTIC FORCES DO NOT CHANGE THE MICROBIOTA OF CANALS AND CHRONIC PERIAPICAL LESIONS: WHEN SHOULD MOVEMENT BEGIN?

Orthodontic forces are light, dissipating and not applied abruptly (Fig 1). These forces should partially compress the periodontal ligament, at a thickness of 0.25 mm and 50% of the volume taken up by blood vessels. They should be light so that they produce tooth movement effectively. If forces are excessive, the connective tissue of the ligament hyalinizes, and osteoclasts and other cells do not resorb bone, nor, therefore, move teeth. This means that excessive force will not be effective.

Orthodontic forces are so light that they do not affect the tissue and cell phenomena that are proper to apical and periapical repair. Cell migration and proliferation are not affected, nor are angiogenesis or collagen synthesis. In addition, orthodontic forces do not affect the microbiota in the canal, the cemental canal and external apical areas.

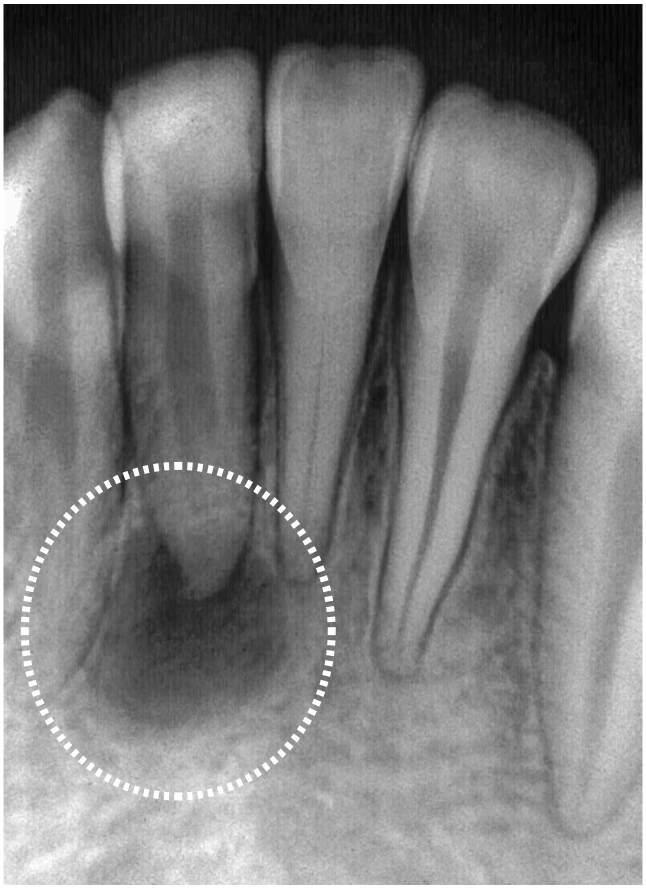

Figure 6 - Chronic periapical lesion compatible with periapical granuloma associated with aseptic pulp necrosis caused by products of tissue necrosis.

Figure 7 - Chronic periapical lesion compatible with immunogenic periapical granuloma treated endodontically in tooth beginning to be moved orthodontically.

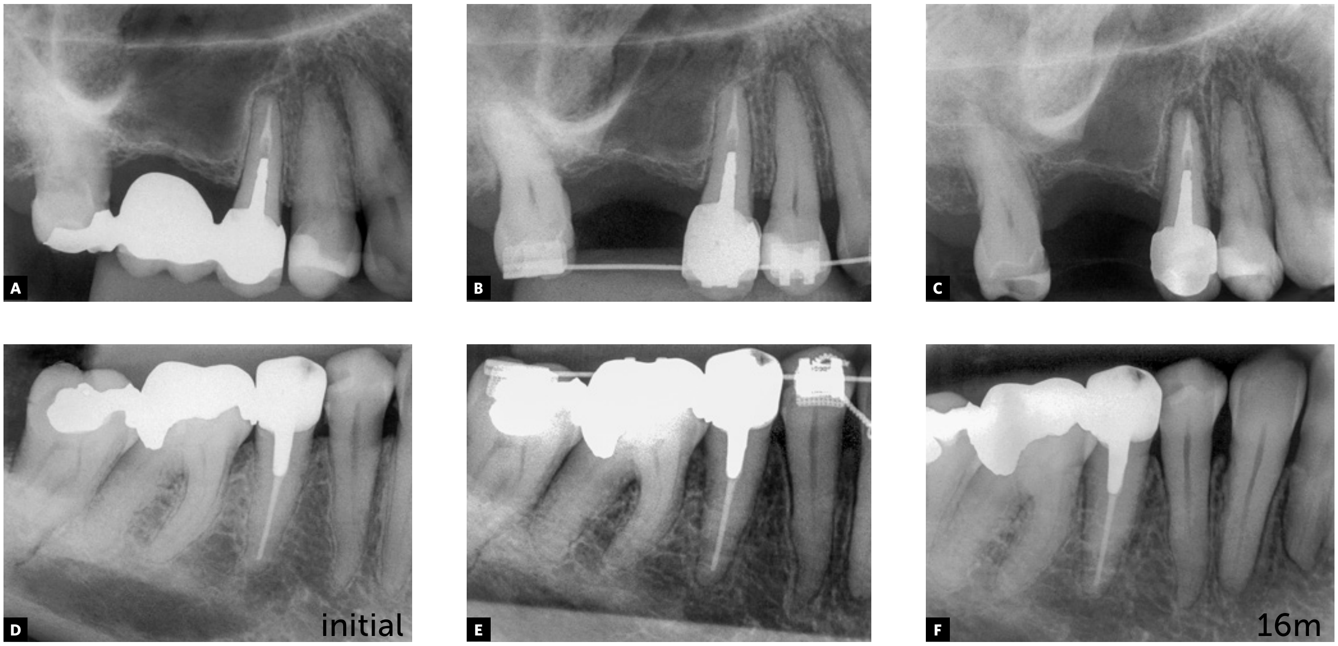

Figure 8 - Premolars endodontically treated and orthodontically moved 16 months after completion of orthodontic treatment. (Case reported by Antônio Geraldo de Oliveira, Varginha, Brazil).

In the past, orthodontic movement of teeth treated endodontically was contraindicated, but today these teeth should be considered normal for orthodontic purposes. No evidence in the literature indicates that tooth movement may be detrimental to the repair of apical and periapical tissues, which includes bone. Such outcomes occur regardless of the time waited before applying orthodontic forces (Figs 7 and 8).

These explanations and the reasoning presented before may allow us to confidently conclude that teeth may be moved soon after endodontic treatment without affecting the repair of apical and periapical tissues (Figs 7 and 8). Treatment may be delayed for 7 to 15, or even 30 days, so that tissues reorganize. In fact, not even this waiting time is necessary. The same applies equally to teeth with or without chronic periapical lesions. These cases should be followed up with periapical images obtained every three months.

Figure 9 - "Pseudo" overfilling associated with external inflammatory apical resorption that may be avoided by delaying permanent canal filling if patient is followed up and there is a collaborative relationship between orthodontist and endodontist. (Case reported by Armelindo Roldi, Vitória, Brazil).

The relationship between the endodontist and the orthodontist should be constructive and collaborative. If orthodontic movement is applied immediately and endodontic treatment fails, failure should be assigned to the technical limitations of all specialties, including endodontics, and not to the fact that the tooth was moved. Orthodontic treatment should not be included as an explanation in studies about the reasons of endodontic failures, as orthodontic movement does not produce this type of failure.

"PSEUDO" OVERFILLING: A MOMENT TO AVOID

What is the best time to fill a canal: when the patient is beginning or in the middle of an orthodontic treatment? The ideal time is when the canal is ready to receive permanent filling, but not before that. A temporary filling should be used while the orthodontic treatment progresses as usual, and this decision should be jointly made by the orthodontist, the endodontist and the patient.

Teeth that have been moved may occasionally present with external inflammatory apical resorptions. If this is the case, and the tooth has permanent filling in the canal, the outcome may be a "pseudo" overfilling, in which cones and filling cements are found beyond the original apical end (Figs 9 and 10).

If the filling is temporary, arrangements for the permanent filling may be made as soon as the orthodontic treatment is completed, and then be contained within current limits of the tooth apex. "Pseudo" overfilling is, thus, avoided. This will be possible only if there is a collaborative and constructive relationship between the orthodontist and the endodontist, and when the patient has the necessary information and agrees with the decision.

APICAL LEAKAGE AND ORTHODONTIC MOVEMENT

Another point to be analyzed in the association of endodontic and orthodontic treatments is the possibility of material leaks into the apical region.

Calcium hydroxide filling materials that leak into the apical region induce the formation of foreign body granulomas around them. However, macrophages can phagocytize their particles, and there will be no more opaque structures on images of periapical tissues six

Figure 10 - Chronic periapical lesion compatible with incipient immunogenic periapical granuloma associated with pulp necrosis. Filling material leaked, and follow up confirmed that it was not aggressive, even 25 months after orthodontic movement. Attention is drawn to "pseudo" overfilling by gutta-percha cone and similar degree of external inflammatory apical resorption in adjacent tooth. (Case reported by Vanessa Bernardini Maldonado, Ribeirão Preto, Brazil).

to twelve months later. This non-aggressive leakage is reabsorbed and does not preclude tooth movement. Therefore, it will not have any significant consequences after tooth movement is completed (Fig. 10).

Fillings with glass ionomer, bioceramics, zinc oxide-eugenol cements, resin cements and gutta-percha cones are not phagocytized or removed by macrophages and osteoclasts. Once they leak out, they will induce the formation of foreign body granulomas around that area, and will remain there for an indefinite amount of time, precluding the complete repair of apical and periapical tissues. Imaging studies at regular intervals may provide information to control this clinical condition without inducing an immune response if the case is asymptomatic or has only a few symptoms. One frequent symptom is sometimes described as a low-intensity pricking pain during mastication, as the apex applies pressure to the material against the bone (Fig 4).

If teeth with accidental leakage of material into periapical tissues have to be moved, orthodontic treatment may be confidently considered. However, periapical images should be obtained every three months to control the position of material in relation to the apex (Fig 10). This is recommended because there may be a more localized apical resorption, specifically associated with the material when the tooth moves towards the material itself. However, this does not have serious consequences for periodontal support.

FINAL CONSIDERATIONS

1. Teeth that received adequate endodontic treatment may be moved, as endodontic treatment is not a contraindication for orthodontic treatment.

2. Apical periodontal repair begins when the cause of periapical or pulp lesion has been eliminated. This occurs immediately after the filling material becomes little or not aggressive to periapical tissues, and particularly if the material is fully contained within the canal.

3. When the filling material leaks into the apical area, a foreign body granuloma forms and then persists for some months or indefinitely, depending on its composition.

4. Materials containing calcium hydroxide with no resin components undergo phagocytosis and disappear from the site in some months, as macrophages gradually remove them.

5. Materials containing resins, silicone, ionomers and zinc oxide-eugenol, as well as bioceramics and gutta-percha, remain in the site and induce the formation of foreign body granulomas. This does not preclude tooth movement, but the patient should be followed up every three months using periapical images to control the position of granulomas in relation to the tooth apex.

6. "Pseudo" overfilling may be avoided if permanent filling is delayed until the endodontic treatment is completed.

A better understanding of these cases may be achieved from the comparison of images of a large number of teeth treated endodontically and moved orthodontically after they have been grouped according to their variables. Observations made in clinical or animal studies may be confirmed statistically, as well as in clinical practice and through random findings during consultancy activities.

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Conception or design of the study: AC, DAOM. Data acquisition, analysis or interpretation: CA, DAOM, RBC. Writing the article: CA, RBC. Critical revision of the article: DAOM. Final approval of the article: CA, DAOM, RBC. Obtained funding: CA. Overall responsibility: CA.

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Comprehensive approach to simultaneous molar intrusion and canine retraction in the treatment of Class II anterior open bite using miniscrew anchorage

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DOI: *https://doi.org/10.1590/2177-6709.25.3.30.e1-12.onl*

Introduction: Anterior open bite is one of the most difficult malocclusions to correct in orthodontic treatment. Molar intrusion using miniscrew anchorage has been developed as a new strategy for open bite correction; however, this procedure still has an important concern about prolonged treatment duration in the patient with anteroposterior discrepancy due to the separate step-by-step movement of anterior and posterior teeth.

Objective: This article illustrates a comprehensive orthodontic approach for dentoalveolar open bite correction of an adult patient, by using miniscrew.

Case report: A woman 19 years and 5 months of age had chief complaints of difficulty chewing with the anterior teeth and maxillary incisor protrusion. An open bite of -2.0 mm caused by slight elongation of the maxillary molars was found. The patient was diagnosed with Angle Class II malocclusion with anterior open bite due to the vertical elongation of maxillary molars. After extraction of the maxillary first premolars, concurrent movements of molar intrusion and canine retraction were initiated with the combined use of sectional archwires, elastic chains and miniscrews.

Results: At 4 months after the procedure, positive overbite was achieved subsequent to the intrusion of maxillary molars by 1.5 mm and without undesirable side effects. Class I canine relation was also achieved at the same time. The total active treatment period was 21 months. The resultant occlusion and satisfactory facial profile were maintained after 54 months of retention.

Conclusion: The presented treatment shows the potential to shorten the treatment duration and to contribute to the long-term stability for open bite correction.

Keywords: Open bite. Orthodontic anchorage procedures. Angle Class II. Tooth movement technique.

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Shear bond strength evaluation of metallic brackets bonded to a CAD/CAM PMMA material compared to traditional prosthetic temporary materials: an *in vitro* study

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Introduction: Orthodontic treatment for adults is currently increasing, and therefore the need to bond brackets to restorations and temporary crowns. The use of CAD/CAM PMMA provisional restorations for orthodontic purposes have not yet been described, and there is currently insufficient information regarding the strength of bracket adhesion.

Objective: This study aimed at evaluating the effects of thermocycling (TC) and surface treatment on shear bond strength (SBS) of brackets to different provisional materials.

Methods: Forty specimens were made from each material [PMMA (Telio Lab), bis-acryl (Telio CS C&B), and PMMA CAD/CAM (Telio CAD)], sandpapered, and divided according to surface treatment (pumiced or sandblasted) and TC (half of the samples = 1,000 cycles, 5°C/55°C water baths) (n=10/group). Stainless-steel brackets were bonded to the specimens (using Transbond XT), and SBS testing was performed. Data were analyzed by three-way ANOVA and LSD *post-hoc* tests ($\alpha=0.05$). Failure types were classified with adhesive remnant index (ARI) scores.

Results: SBS values ranged from 1.5 to 14.9 MPa. Sandblasted bis-acryl and sandblasted auto-curing PMMA groups presented similar values ($p>0.05$), higher than the CAD/CAM material ($p<0.05$), with or without TC. When thermocycled, pumiced bis-acryl showed higher SBS than pumiced acrylic ($p=0.005$) and CAD/CAM materials ($p=0.000$), with statistical difference ($p=0.009$). TC showed negative effect ($p<0.05$) for sandblasted bis-acryl and pumiced acrylic groups. ARI predominant score was mostly zero (0) for CAD/CAM, 1 and 2 for bis-acryl, and 1 for acrylic groups.

Conclusion: In general, bis-acryl material showed the highest SBS values, followed by acrylic and CAD/CAM materials, which showed SBS values lower than an optimum strength for bonding brackets.

Keywords: Air abrasion. Bonding agents. CAD/CAM. Orthodontics. Acrylic resins.

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INTRODUCTION

The search for orthodontic treatments by adults is currently increasing, not only because of esthetics, but also because of frequently being an intermediate stage on oral rehabilitation.[1] Facing this new scenario, orthodontists often need to bond brackets to restorations and temporary crowns, since adult dentition is usually characterized by restorative treatments.[2] An issue regarding this procedure relies on the fact that bonding brackets to restorative materials is claimed to be more difficult than to natural teeth.[2,3] Although not many studies have been performed on provisional restorations,[2-8] some showed less than the minimum bonding necessary to be able to perform tooth movement in the orthodontic treatment.[2,3]

Factors including physical, mechanical, handling properties and biocompatibility might influence the choice of a material for provisional restorations,[1] which should work as protection of the pulpal tissues, and present esthetics and oral functions.[9]

Traditionally, provisional restorations are made from auto-curing polymethylmethacrylate (PMMA) resins.[6] However, these are prone to discoloration and can cause chemical irritation or allergic reactions during polymerization.[10] Also, their polymerization shrinkage can cause marginal discrepancies in the provisional crowns.[11] A new class of material, the bis-acryl resins, shows low exothermic reaction during setting, with better strength, marginal adaptation and contour.[12] Another class of provisional material involves a novel technique, the computer-aided design/computer-aided manufacturing (CAD/CAM) materials. The emergence of this technology allowed for high precision materials, since restoration is milled from pre-polymerized blocks of the provisional material, thus, any degree of polymerization shrinkage occurs during processing of the block and not intra-orally.[9] Moreover, this indirect material presents higher fracture strength and lower marginal gap than direct techniques such as bis-acryl resins.[9] However, one disadvantage is the cost, in comparison to conventional provisional restorations.[9] The use of CAD/CAM PMMA provisionals for orthodontic purposes had not yet been described in literature.

Although a well-known technique has been used to bond brackets to natural teeth, when it comes to provisional materials, no technique has been specifically described. A strong bond of composite to enamel has been possible since the introduction of the use of phosphoric acid in dentistry, by Buonocore.[13] Since then, different techniques have been studied to improve bond strength of brackets to different surfaces, such as sandblasting or air abrasion,[14] pulsed lasers[15] and surface roughening with a bur.[5]

A clinically acceptable adhesive resistance for bracket bonding has been claimed to vary from 6 to 8 MPa,[16,17] where brackets bonded to provisional materials must be strong enough to resist dental movement, but weak enough to be removed without damaging the bonded surface when treatment is finished. Excessive bond strength is undesirable, since it does not allow for smooth debonding, without damaging the restorative surface.[18]

In order to evaluate bonding of brackets to different surfaces *in vitro*, thermocycling can be used as an accelerated aging test.[19] Temperature changes between the water baths could contribute to water contamination at the resin bond interface, thus weakening the resin.[20]

Therefore, the aim of this study was to evaluate the effect of thermocycling (TC) and surface treatment on shear bond strength of metallic brackets to different provisional prosthetic materials. The hypothesis tested was that different provisional materials present different bond strengths to metallic brackets. The use of different surface treatments might result in different shear bond strengths; and TC results in lower bond strengths compared to groups without TC.

MATERIAL AND METHODS

One hundred and twenty samples were fabricated according to the provisional prosthetic material used, surface treatment and TC (n = 10 per group). Group setting can be seen on Figure 1. Forty cylindrical specimens (7-mm diameter x 2-mm thick) were made from each material, according to manufacturer's instructions: PMMA auto-curing acrylic resin (Telio Lab, Ivoclar Vivadent, Schaan, Liechtenstein) and bis-acrylic resin (Telio CS C & B, Ivoclar Vivadent, Schaan, Liechtenstein). Regarding the CAD/CAM PMMA material (Telio CAD, Ivoclar Vivadent, Schaan, Liechtenstein), blocks were cut (6mm x 8mm x 2mm thick) with a slow speed diamond saw (Mecatone T180, Presi, Eybens, France). Surfaces from all materials were polished with

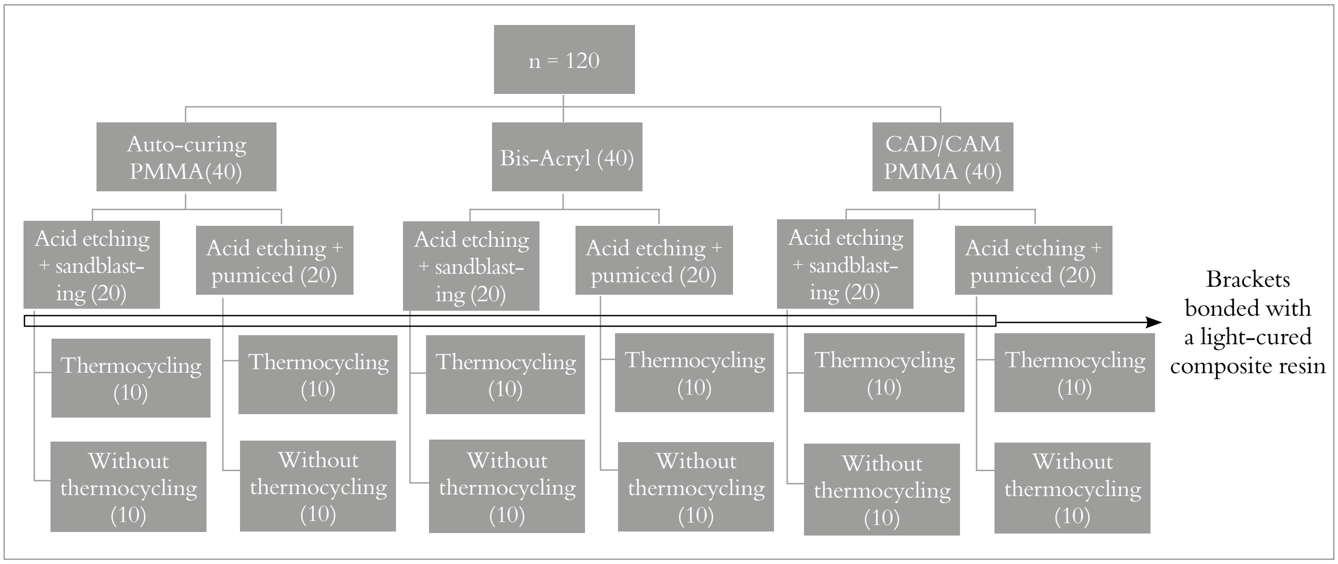

Figure 1 - Illustration of the groups' setting process.

120-, 500- and 1000-grit SIC paper discs respectively, for 20s (each grit) (Labopol-6, Struers, Westlake, Ohio, USA), being washed and cleaned in between discs.

After that, samples from each material were randomly and equally subdivided into two groups regarding surface treatment: pumice slurry on a prophylaxis brush for 5 seconds or sandblasting (50-µm Al_2O_3 particles at 10-mm distance for 5 seconds - Microjato Standard, BioArt, São Carlos/SP, Brazil). Following this procedure, all prosthetic surfaces underwent acid etching with phosphoric acid for 30s, in order to clean the samples' surfaces and remove any possible oil or debris from the sample-making process. Maxillary central incisors brackets with a micro-etched 80-gauge mesh base (Gemini, 3M Unitek, Monrovia, California, USA) were bonded with a light-cured composite resin (Transbond XT, 3M Unitek, St. Paul, MN, USA) according to manufacturer's instructions, using a LED light-curing unit (Bluephase Style 20i, IvoclarVivadent, Schaan, Liechtenstein). This procedure was performed by a single operator in order to standardize the steps (Fig 2). Then, samples were stored in a controlled atmosphere at 100% humidity for 24h. After that, half of the samples from each group were subjected to a shear bond strength (SBS) test at a cross-head speed of 0.5mm/min until failure, in a shear bond strength tester (Shear Bond Tester, Bisco Dental, Portland, OR, USA) (Fig 3). The other half of the samples underwent a TC procedure applying 1,000 cycles of alternating 5°C and 55°C water baths (30s each), followed by the SBS test procedure, as previously described. Although ISO/TR 11405[21] recommends 500 cycles as a methodology for aging studies, a lack of difference between groups when using this amount of cycles has been observed, which is the reason why, in the present study, this value was doubled. SBS values were obtained in Newtons and converted to MPa.

After debonding, each specimen was analyzed under a loupe (Panoramic Flip-up Adivista 2.5x; Peri-Optix Inc., Lompoc, CA, USA) at 2.5 times magnification, to evaluate failure, described through the adhesive remnant index (ARI)[22]: ARI 0 (0% on sample, 100% on bracket), ARI 1 (<50% on sample, >50% on bracket), ARI 2 (>50% on sample, <50% on bracket), or ARI 3 (100% on sample, 0% on bracket).

SBS data were analyzed using three-way analysis of variance and compared with LSD's *post-hoc* tests, at $\alpha = 0.05$.

RESULTS

Table 1 summarizes the mean and standard deviation of SBS determined for each material, according to surface treatment and TC. A significant statistical difference was found among groups ($p < 0.05$). SBS values ranged from a minimum of 1.5 MPa (pumiced CAD/CAM material with TC), to a maximum of 14.9 MPa for the sandblasted bis-acryl material without thermocycling.

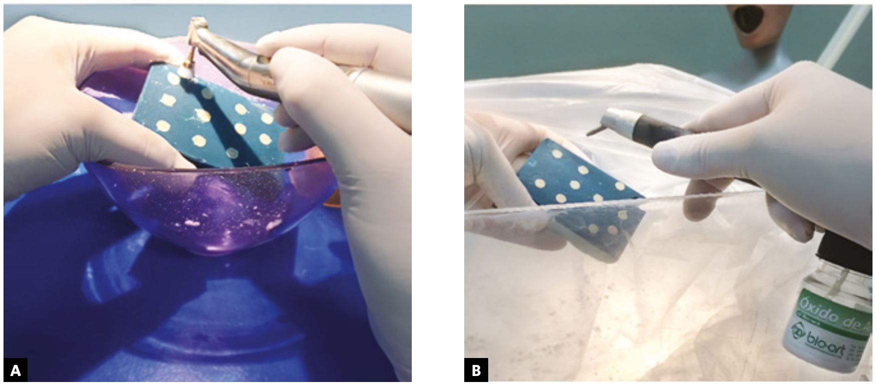

Figure 2 - Photographs of the surface treatment process: **A**) surfaces polishing with pumice slurry; **B**) sandblasting of the samples with 50-µm Al_2O_3 particles.

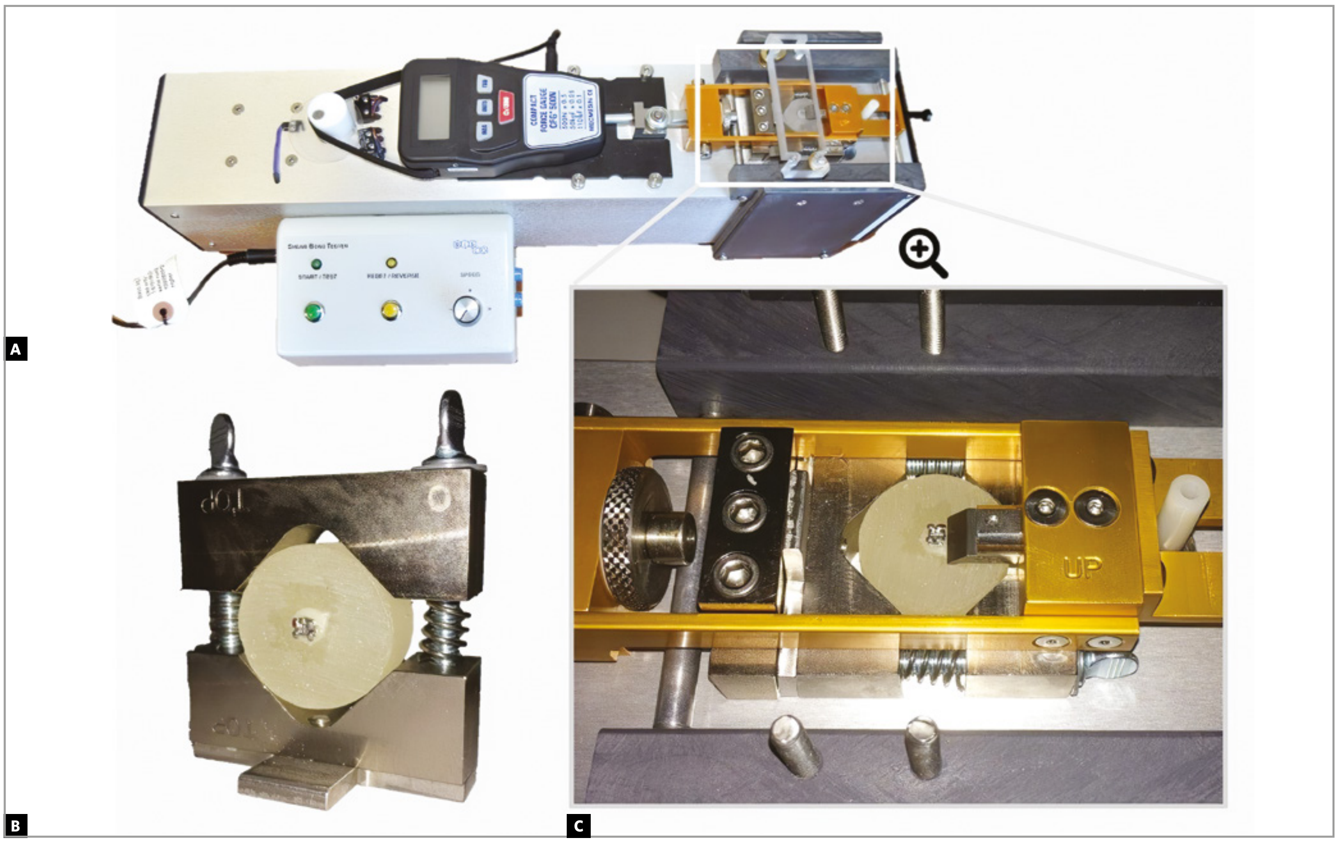

Figure 3 - **A)** Image showing the Shear Bond Tester® device in a panoramic view. In (**C**), it is possible to observe a photographic close-up of the area where the machine generates the shear force on the bracket, which is bonded to a cylindrical sample of provisional prosthetic material, until the adhesive failure occurs. In (**B**), it is possible to observe the test object, which is held by the specially designed support of the machine.

Table 1 - Means (SD) of different materials regarding surface treatment and thermocycling (values in MPa).

TC	Material	Treatment	
		Sandblasted	Pumiced
Without	CAD-CAM	3.2 (1.6)^{Ba}	4.0 (2.0)^{Ba}
	Bisacryl	14.9 (4.2)^{Aa}	13.9 (5.3)^{Aa}
	Acrylic	13.7 (3.6)^{Aa}	11.1 (2.1)^{Aa}
With	CAD-CAM	2.7 (2.3)^{Ba}	1.5 (0.8)^{Ca}
	Bisacryl	11.4 (4.1)^{Aa}*	11.4 (5.1)^{Aa}
	Acrylic	12.1 (4.7)^{Aa}	6.2 (3.5)^{Bb}*

Means followed by different letters (uppercase in vertical and lowercase in horizontal) differ from each other ($p < 0.05$) within the same group of cycling.
* Differs from before and after thermocycling in the same material and surface treatment ($p < 0.05$).

The bis-acryl material showed the highest SBS values when compared to other materials, regardless of the type of treatment or TC, while the CAD/CAM material showed the lowest values. When no TC was performed, the bis-acryl and the acrylic materials were not significantly different from each other for any treatment ($p > 0.05$), although both materials showed higher SBS values when compared to the CAD/CAM material, for any treatment ($p < 0.05$). When no TC was performed, both sandblasting or pumiced treatments performed statistically similar for all materials ($p > 0.05$); while when TC was performed, the acrylic material showed a statistically significant difference ($p = 0.001$), favoring the sandblasted, compared to the pumiced group, which was almost twice the value, when compared.

When TC was performed, sandblasted bis-acryl and acrylic materials performed statistically similar ($p = 0.656$), both showing higher SBS values than the CAD/CAM material ($p < 0.05$). However, when TC and pumice were performed, the bis-acryl material was statistically superior to the acrylic ($p = 0.003$) and CAD/CAM ($p = 0.000$) materials, followed by the acrylic material and lastly the CAD/CAM material, also statistically different within each other ($p = 0.009$).

When TC was compared to without-TC, the only groups that showed a statistically significant difference were the sandblasted bis-acryl material ($p = 0.030$), that showed higher SBS values when no TC was performed, and the pumiced acrylic material, showing the same pattern ($p = 0.005$).

Figure 4 shows the results from the Adhesive Remnant Index (ARI) types for all groups. It was noted that failures were different for each material, being a predominant ARI = 0 for the CAD/CAM groups, a predominant ARI = 1 and ARI = 2 for the bis-acryl groups, and ARI = 1 for the acrylic groups. It was observed that, for the bis-acryl, a great amount of specimens showed failure within the sample, meaning that the adhesion was so strong that instead of fracturing the adhesive interface, the specimen cohesively fractured, thus detaching the bracket. This did not occur with the CAD/CAM material, and rarely happened with the acrylic material.

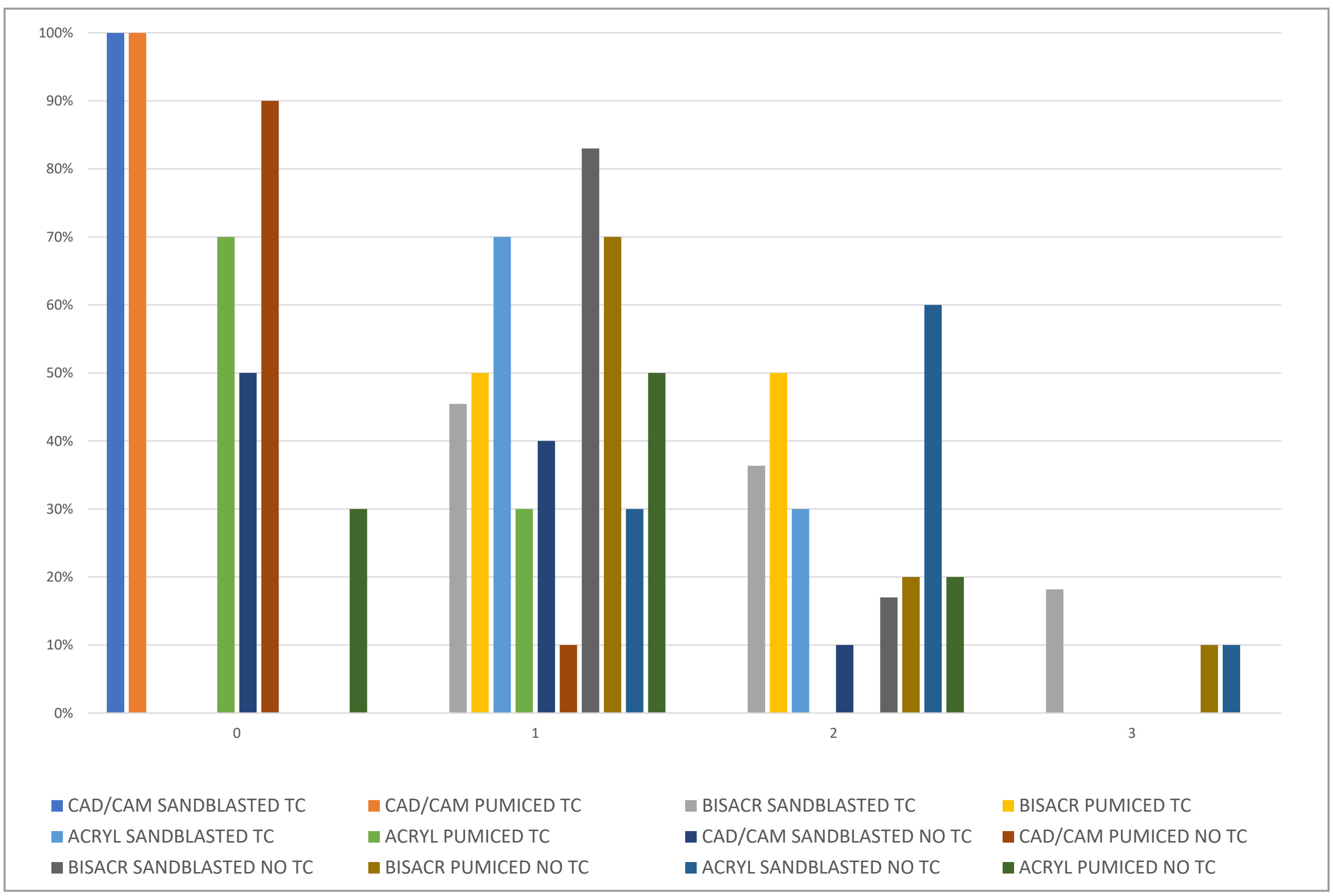

Figure 4 - Results from the Adhesive Remnant Index (ARI) per group.

DISCUSSION

This study evaluated SBS of brackets using a novel material technology for provisional restorations — results that have not been studied so far. Results from this study showed that significant changes occur on bond strength when independent variables, such as materials, surface treatment and thermocycling, are tested.

The first tested hypothesis was accepted, since different materials promoted different SBS to metallic brackets. In general, the bis-acryl material promoted the higher SBS values when the different materials were compared, although for most of the groups it performed similar to the acrylic resin. The acrylic material showed lower SBS values than the bis-acryl material when both groups were pumiced and TC was performed, which is in agreement with a previous study.[6] However, sandblasting produced statistically similar results for both materials, which is also in agreement with a previous study.[23] When the CAD/CAM PMMA provisional material was evaluated, it showed the lowest SBS values, independent of surface treatment and TC — a material that has not been studied so far for brackets bonding.

The higher SBS of bis-acryl and acrylic materials, compared to the CAD/CAM material, can be explained because their basic components are methacrylates; thus, bonding is likely to be influenced by the number of available reactive sites on the polymerized provisional materials.[3] Moreover, the bis-acryl material contains bifunctional acrylates, with available bonding sites and cross-link to provide increased mechanical strength and resistance to weakening in the presence of water.[24] On the other hand, PMMA CAD/CAM blocks are pre-polymerized blocks, and thus, a material with greater density and fewer potential bonding sites, the same process that occurs in traditional denture teeth,[23,25] contributing to their low SBS to metallic brackets. Although this material presents a high fracture strength, low polymerization shrinkage, and excellent marginal adaptation,[9] this study showed that it is not indicated for orthodontic movements applied to a provisional restoration, due to the unacceptable SBS results.

Although ARI score remained almost absolutely equal to 0 in the CAD/CAM materials for all groups, no surface damage was observed, meaning that adhesion was poor and promoted total debonding of bracket/resin from the sample, while the material resisted to shear bond forces. On the other hand, most of the bis-acryl material's samples showed a degree of restoration surface damage, correlated to the high bond strength of this material to the orthodontic cement. Although damage occurred, an important characteristic regarding this material relates to its ease of repair with a composite resin.[23,26,27] Moreover, it possesses other advantages over acrylic resins, such as superior handling characteristics, ease of manipulation, less porosity, low polymerization shrinkage and good color stability.[23,26,27]

When surface treatment was compared, a significant difference was observed only for the acrylic group after TC, with pumiced group presenting lower SBS values than sandblasted group. Thus, the second hypothesis was partially accepted. The difference was twice the value, meaning that sandblasting is indicated for the long-term success of bracket bonding to acrylic provisionals. Moreover, results from pumiced acrylic restorations after TC performed at the exact acceptable value for bracket bonding; thus, it is likely that over time those values could decrease to an unacceptable point. There is an increase of SBS for brackets bonded to sandblasted polycarbonate crowns, while non-sandblasted (control) crowns produced statistically lower SBS,[5] which is in accordance with the present study. When the ARI was evaluated, for all materials, more frequent ARI = 0 values were observed when pumiced was compared to sandblasted. An ARI = 0 represents that no orthodontic composite remained adhered to provisional material, possibly due to the high adhesion values between the bracket and the adhesive system,[28] and thus lower adhesion values between the orthodontic composite and the provisional material. An exception is made for the bis-acryl material, where both sandblasted and pumiced groups behaved similarly and ranging mostly from ARI = 1 to ARI =2, for both with and without TC. The present study used a magnification of 2.5x to evaluate the ARI of all samples; however, it has been described that ARI scores observed through different magnifications (from 10x to 20x) can present significantly different results.[29] Thus, future studies should focus on the visualization of ARI scores with increased magnification.

The third hypothesis was also partially accepted, since two groups presented a statistical difference when compared before and after TC. Sandblasted bis-acryl material presented significantly higher SBS values when no TC was performed, compared to when it was. However, both values were considered way above the acceptable threshold for brackets bonding, which are usually considered from 6 to 8 MPa.[16,17] The same pattern occurred for the pumiced acrylic material; however, when this group underwent TC, SBS values remained at the exact value of tolerance for a bracket bonding to be acceptable. Thus, likely with longer aging procedures, it would present values below the acceptable limits. Therefore, when acrylic materials are used for orthodontic purposes, sandblasting is highly indicated.

Results from this study suggest that bis-acryl and acrylic materials should be preferred against the CAD/CAM material, when bonding of brackets are to be performed within the tested conditions. However, for the acrylic materials, sandblasting is paramount for achieving positive long-term results. Possible solutions regarding improving brackets adhesion to CAD/CAM PMMA materials should be studied, such as promoting micromechanical retentions in order to increase surface area, or by using silane coupling agents, which has shown to improve shear bond strength between resin composite cements and different materials such as ceramics.[30]

This study followed the manufacturer's recommendation on brackets cementation with the system used; however, further studies should focus on longer aging times and, mostly, on using extra adhesive steps or different surface treatments, in order to improve bracket adhesion to CAD/CAM PMMA materials, as this material is being increasingly used in dentistry, showing good properties regarding marginal fracture strength, low marginal gap, and no polymerization shrinkage in mouth.[9]

CONCLUSIONS

Within the limitations of this *in vitro* study, it can be concluded that the evaluated bis-acryl material showed the highest shear bond strength results when all variables were considered, although when sandblasting was performed, values for this material and the acrylic resin remained statistically similar, both with or without TC. If the auto-curing acrylic resin is the material of choice for the provisional restoration, the orthodontist should sandblast the provisional restoration before bracket adhesion, in order to obtain longer successful results. The PMMA CAD/CAM material showed an insufficient SBS to metallic brackets within the tested conditions.

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Effect of rapid maxillary expansion on nasal cavity assessed with cone-beam computed tomography

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Introduction: Rapid maxillary expansion (RME) is assumed as a well established procedure; although, some effects on facial complex are not yet fully understood.

Objective: The aim of this research was to verify, using cone-beam computed tomography, the effect on linear dimensions of the nasal cavity.

Methods: Sample consisted of twenty patients aged 7 to 16 years, with skeletal deformity that justified the use of CT scans, and who required the RME as part of the orthodontic treatment planning. Scans were taken before clinical procedures were performed (T_0) and after stabilizing the expander screw (T_1). Dolphin Imaging v. 11.5 3D software was used to measure six areas on nasal cavity: three at the anterior portion (upper, middle, and lower) and other three at the posterior portion (also upper, middle, and lower). Data were statistically treated using Shapiro-Wilk test to verify normality. Differences between T_0 and T_1 were calculated using the Spearman correlation and paired Student's *t*-test, with a significance level of 5%.

Results: All linear measurements presented a significant increase ($p < 0.05$) after RME, both in the anterior and posterior regions, suggesting some parallelism on the opening pattern, especially at the lower portion ($p < 0.001$).

Conclusions: RME was able to significantly modify the internal dimensions of the nasal cavity.

Keywords: Maxillary expansion. Nasal cavity. Cone-beam computed tomography.

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INTRODUCTION

Rapid maxillary expansion (RME) is an orthodontic and orthopedic procedure that has been used for over 100 years for correction of maxillary atresia.[1-4] RME orthopedic action basically occurs by opening the median palatine suture, which guarantees a real skeletal gain in transverse dimension of the maxilla. Additionally, it also has the potential to alter the internal dimensions of the nasal cavity, promoting reduction of nasal resistance, increase in air flow and even a favorable change at the patient breathing pattern.[1,5-13]

Most studies related to this therapy have been conducted on the basis of occlusal and cephalometric radiographs, especially due to the fact that these exams are important for orthodontic treatment planning and are commonly part of the set of exams requested for this purpose.[1,5,8,14-20] Nevertheless, in spite of being capable of providing great information, radiographs are two-dimensional images of a three-dimensional structure.[21]

Although many studies have been conducted about RME, there is still no consensus in the literature about the real effects of this procedure on the respiratory pattern.[6,9,11,13,17,22-25] Methodological difficulties and lack of standardization of research evaluating the morphological changes that actually occur in the nasal cavity are common limitations. Currently, with the advent of cone beam computed tomography (CBCT), these problems have been minimized, since the CBCT enables acquisition of efficient and precise reproductions of anatomical structures.[26-28] CBCT has been introduced on dental literature as an innovation in the way of acquiring volumetric images,[12] with subsequent multiplanar reconstruction.[24]

A great number of researches evaluating the effects of RME using CBCT have been developed over the last few years,[28-33] most of them focusing on volumetric changes,[10,12,23,25-27,34-38] although it is also very important to analyze changes in linear dimensions. In this context, methods that allow a more objective analysis of linear changes induced by expansion are anticipated. Therefore, the aim of this research was to verify the effect of RME on linear dimensions of the nasal cavity using CBCT.

MATERIAL AND METHODS

The present study was performed in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) and the Ethics Board of the Brazilian Ministry of Health (Resolution CNS/MS 466/2012) for research involving humans. This project was approved by the independent Ethics Committee of the School of Dentistry of Federal University of Bahia (Protocol #26/12) and registered with SISNEP FR 459942, CAAE 0028.0.368.000-11. The privacy rights of all subjects were observed, no identifying information of them was used, and written informed consent was obtained from all participating parents or legal guardians.

For this research, 20 patients ranging from 7 to 16 years of age were selected among those who sought the Federal University of Bahia orthodontics postgraduation program. The inclusion criteria involved: normal general health condition, no previous orthodontic treatment, no active caries and/or periodontal disease, need for RME as part of orthodontic treatment planning, and a vertical (hypo or hyperdivergent) or sagittal (Class II or Class III skeletal pattern) dentofacial deformity that would justify requesting a CBCT. Based on the literature[36] and on the pilot study performed, the sample size was calculated (Table 1).

Selected patients were submitted to a new clinical exam, and before insertion of any accessory, a CBCT of the whole skull was taken (T_0). RME was performed with a Haas expansion appliance, with bands on the permanent first molars, and depending on the patient's stage of dental development, on the first premolars or primary first molars.

Treatment included an active stage, which released lateral forces, and a passive stage of splinting. The active stage started 24 hours after appliance setting, and involved activating the screw twice a day. The activation stage lasted from two to four weeks, depending on the amount of expansion desired. At the end of this stage, the screw was stabilized with 0.012-in ligature wire (Morelli, Sorocaba/SP, Brazil), and a new tomography was taken (T_1), with the aim of verifying the impact of expansion in all skeletal disharmonies presented by the patients. Appliances remained without activation for six months, while reorganization of maxillary suture was processed.

Table 1 - Sample calculation based on literature[36] and pilot test.

Sample calculation	
Standard deviation of difference	1.21
Average of the differences (after and before)	1.41
Level of significance	5%
Power of test	95%
Required sample size for each group	19

In order to obtain the CBCT, an i-CAT® (Imaging Sciences International, Hatfield, PA, USA) equipment was used, with acquisition protocol configured at 120 kVp, 30 mA, voxel of 0.2 mm, FOV of 20 *x* 25 cm, acquisition time of 40 seconds, with an effective radiation dose of approximately 69 μSv. Patients were placed with Frankfort plane oriented parallel to the ground and with maximum habitual intercuspidation. In all patients, special attention was addressed to the position of the tongue, which had to be positioned on the central incisal papilla throughout the entire exam. DICOM (Digital Imaging and Communications in Medicine) files were imported and three-dimensional (3D) reconstructions of maxillary structures were performed using the Dolphin Imaging software v. 11.5 Premium (Dolphin, Chatsworth, CA, USA). After 3D reconstructions, the nasal cavity was delimited and the linear dimensions were calculated.

Before taking measurements, it was necessary to standardize the position of the head, according to axial, coronal and sagittal planes, selected in both phases of the study. In lateral views, the right Orbital and Porion points were located and positioned in order to leave Frankfort plane coinciding with the software horizontal line. In frontal views, equivalent points in right and left zygomatico-frontal sutures were also marked and positioned in such a way to coincide with the software horizontal line, and the software median line positioned exactly in the patient's median line.

After this standardization, reconstructions were also used to determine sagittal and axial sections. Reference lines were then identified, with the purpose of standardizing images so that the linear dimensions of the nasal cavity, before and after expansion, could be measured. Initially, in sagittal slices, the vertical reference line was placed over the anterior nasal spine, and the horizontal reference line was placed on the most inferior portion of nasal cavity (Fig 1). In axial sections, the reference line was placed along the median palatine suture, indicating its exact location. Afterwards, also in sagittal sections, the vertical reference line was placed over the posterior nasal spine, and the horizontal reference line was also placed on the most inferior portion of the nasal cavity (Fig 1). Thus, coronal sections could be generated and measurements taken both in the most anterior and in the most posterior regions of nasal cavity.

In coronal sections, specific tools of the software were selected to measure the desired distances. The area of interest was chosen by moving the reference lines, with the horizontal line being placed over the nasal cavity base, and another vertical line, which had previously been positioned, in axial sections, in the median sagittal region. The main marker was placed on the meeting point between these two lines. Then, the horizontal reference line was repositioned to the nasal cavity top, and a new marker was placed on the intersection of these lines, determining the height of the nasal cavity. The vertical reference line was then repositioned to determine the lateral limits in the superior, middle and inferior portions of the nasal cavity, and new markers were placed in these regions to measure the linear distances. After obtaining all measurements in the most anterior region, measurements in the most posterior region were taken (Fig 2).

Values obtained in each measurement were compiled using the Microsoft Office Excel 2010 (Microsoft Office 2010, Washington, WA, USA), and analyzed using the SPSS version 16.0 (SPSS Inc., Chicago, IL, USA). Initially, a descriptive analysis was made (mean and standard deviation) with the purpose of identifying the general and specific characteristics

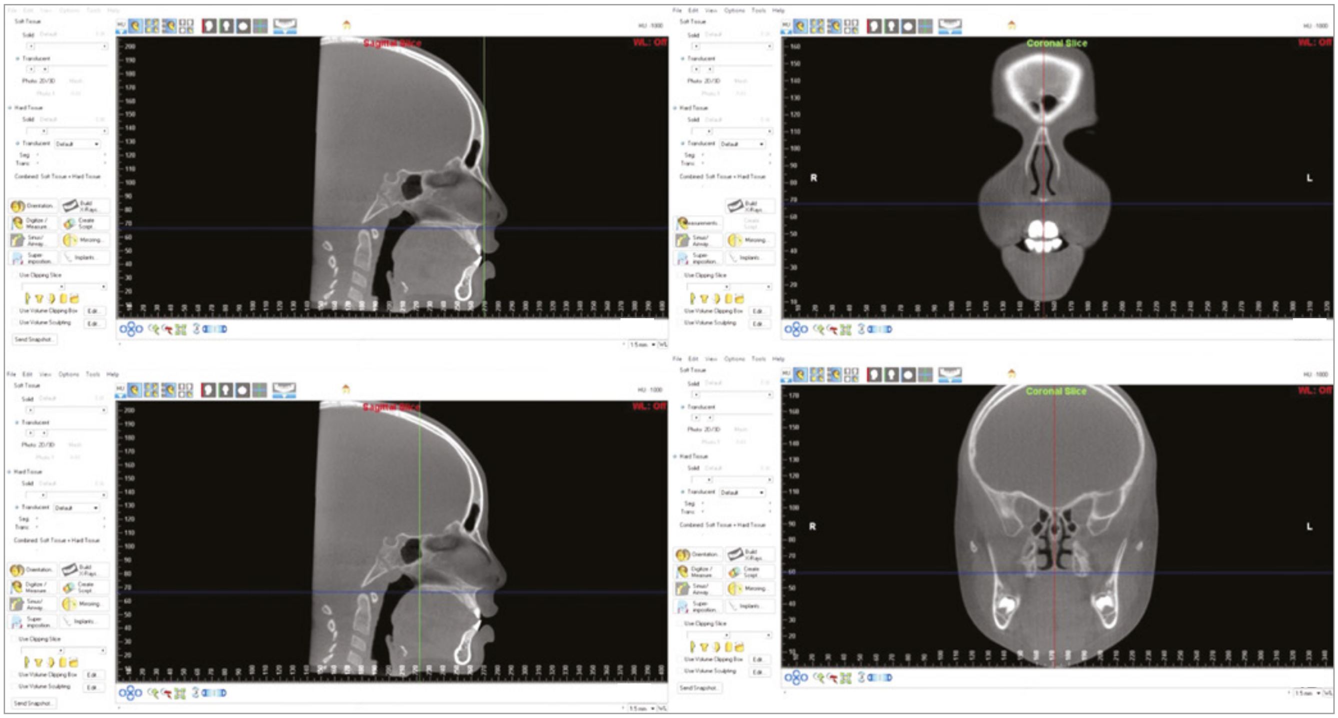

Figure 1 - Standardization of positioning of the digital image of the head, in sagittal and coronal sections, using the Dolphin Imaging software v. 11.5 Premium.

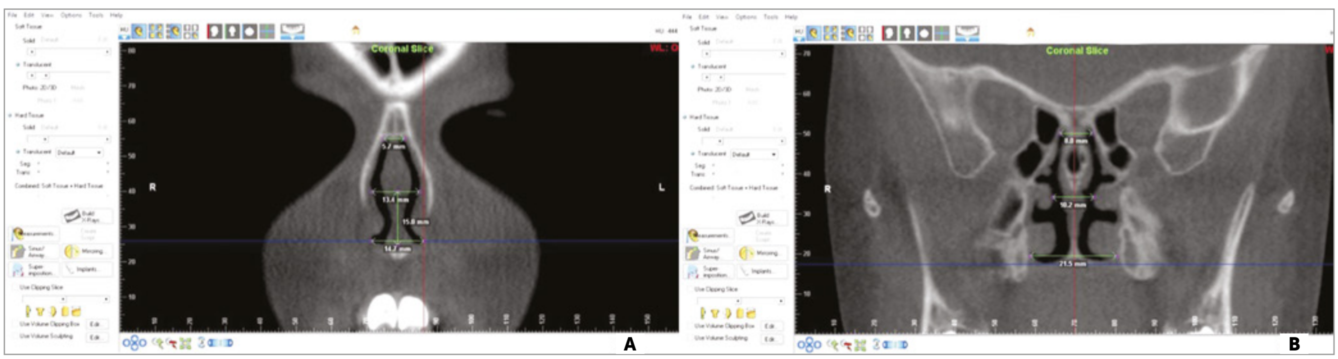

Figure 2 - Determination of linear limits of the nasal cavity, in superior, middle and inferior portions, on coronal sections of (**A**) anterior and (**B**) posterior regions.

of the studied sample. All the measurements were taken by the same evaluator, duly calibrated. Eight coronal sections (10% out of a total of 80 images), randomly selected, were examined once again after 15 days, and used to calculate the causal error for all the variables, by means of the Lin's concordance coefficient, in order to verify the intra-examiner agreement (confidence interval of 95%), and systematic error. An index higher than 0.93 was obtained for all variables. Data distribution normality was verified with the Shapiro-Wilk test. Differences between T_0 and T_1 values were calculated for all the measurements using the Spearman correlation and paired Student's *t*-test, with a significance level of 5%.

RESULTS

The mean, standard deviation and *p*-value for measurements of each region are demonstrated in Table 2, in both T_0 and T_1 phases. It is possible to observe that all measurements showed a significant increase. In Table 3 and Figure 3, differences between T_1 and T_0, in the different measured regions, are shown. The Spearman correlation test revealed an index of 0.989, considered a strong correlation.

Table 2 - Mean, standard deviation and *p*-value for each region, pre (T_0) and post-RME (T_1) phases.

Region	Times T_0 Mean (mm)	T_0 Standard deviation (mm)	T_1 Mean (mm)	T_1 Standard deviation (mm)	p-valor
Anterior					
Superior	6.235	1.263	6.605	1.047	0.044*
Middle	12.675	1.452	13.54	1.796	<0.001*
Inferior	14.820	1.979	16.175	2.228	<0.001*
Posterior					
Superior	9.765	5.689	10.105	5.893	0.011*
Middle	17.500	5.961	18.230	6.056	0.008*
Inferior	18.575	5.477	20.005	5.559	<0.001*

* Statistically significant difference (p < 0.05).

Table 3 - Linear changes (mm) between pre- and post-RME phases (T_1-T_0).

	T_1-T_0 Region	Difference (mm)
Anterior	Superior	0.425
	Middle	0.835
	Inferior	1.27
Posterior	Superior	0.31
	Middle	0.73
	Inferior	1.355

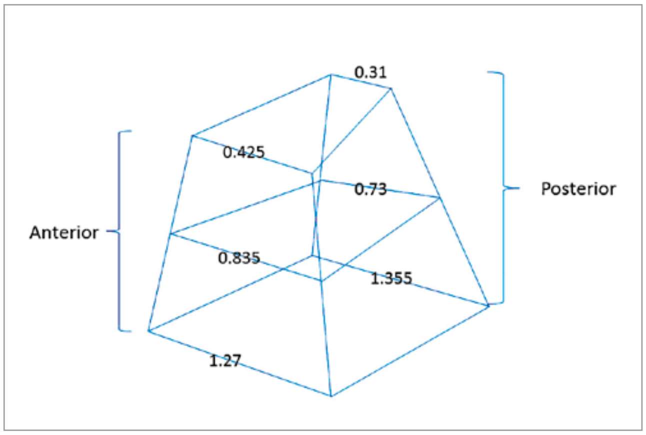

Figure 3 - Representation of the opening pattern of anterior and posterior regions, and superior, middle and inferior portions, of the nasal cavity after RME.

DISCUSSION

Studies conducted over the course of many years about possible alterations in nasal cavity resulting from RME were based on occlusal or lateral and frontal cephalometric radiographs.[1,5,7,8,11,13,15,17-19] These studies state that the width variation of the nasal floor is about 0.4 mm to 6.5 mm. However, they should be considered with caution, because they were based on two-dimensional images with a great amount of superimpositions. Most recent research has been conducted using three-dimensional imaging,[10,12,24,25,27-33,36-38] but few have evaluated changes in linear dimensions of the nasal cavity.[10,36] In this research, the most inferior part of the nasal cavity showed an increase in width from 0.3 mm to 3.8 mm. These values are lower than that cited previously, but the greater precision and richness of details of tomographic images may explain these differences. In addition, although some studies have evaluated skeletal and volumetric changes after RME using CBCT,[10,12,21,23-27,29-31,34-38,40] none have evaluated the changes in linear dimensions.

Opening of the median palatine suture during RME, both in coronal and axial views, has been shown in various studies[2-4] to be triangular in shape, with its vertex facing towards the nasal cavity in the coronal view, and towards the posterior nasal spine in the anteroposterior direction. This triangular configuration is controversial in the literature, because some studies have shown that the opening occurs with the suture edges almost parallel to each other.[16,31,39] Recently, authors in two systematic reviews[33,40] concluded that there is no consistent evidence for the pattern of opening of the median palatine suture, whether parallel or triangular. However, these findings refer to studies conducted considering the bony part of the palate of the oral cavity, and no studies have been found in which this evaluation was performed directly on the floor of the nasal cavity. In this research, in coronal views, it was possible to verify a great transverse movement in the inferior portion of the lateral walls of the nasal cavity, both in anterior and posterior sections, and consequent distancing of the nasal conchae in relation to the nasal septum. This improvement in linear dimensions was gradually decreased towards the frontonasal suture (Fig 3), with values of approximately 1.3 mm, 0.8 mm and 0.4 mm, in anterior sections, and 1.4 mm, 0.7 mm and 0.3 mm, in posterior ones (Table 3). This is in accordance with the literature, which states that in coronal view the opening occurs in a triangular form, with the apex facing towards the frontonasal suture.

However, in axial sections, the opening pattern seems to be slightly different. The most inferior portion of the anterior and posterior regions presented a similar gain in the transverse direction, 1.3 mm and 1.4 mm, respectively (Table 3). These values indicate that the movement of the lateral walls of the nasal cavity was uniform (Fig 3), suggesting that the suture opening was parallel, as shown by other authors.[16,31,39] Although these changes are statistically significant, they are not clinically relevant for orthodontics, particularly at the higher portions of the nasal cavity.

It is worth pointing out that, according to the literature,[7-11,17-19] although the gain at the inner dimensions of the nasal cavity after RME procedure may be significant, its use for respiratory purposes only is not justified. Recently published studies[12,13] showed an improvement in the respiratory pattern in mouth breathers. However, there is no scientific evidence indicating that children treated with expansion preserve the respiratory benefits acquired after a follow-up period, thus emphasizing the need for further long term studies.

CONCLUSION

In view of the foregoing, it is possible to conclude that RME was effective in significantly increasing the internal dimensions of the nasal cavity, both in the anterior and posterior regions, and both in the inferior and superior portions, with two different patterns. In the coronal view, opening is triangular in shape, with its vertex facing towards the frontonasal suture. In the axial view, there is a uniform movement of the lateral walls, especially in the most inferior portion.

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Effect of three different attachment designs in the extrusive forces generated by thermoplastic aligners in the maxillary central incisor

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Introduction: Orthodontic aligners use have increased in dentistry. The resolution of complex movements such as extrusion demands the use of attachments to reach the aimed force, but just a few studies have been developed to evaluate the biomechanical performance of the aligners and their accessories.

Objective: The objective of this study was to evaluate on the three axes (X, Y and Z) the forces generated by three different attachment designs for the extrusion of the maxillary central incisor using esthetic orthodontic aligners.

Methods: Three prototypes of maxillary models were developed, each one with a specific attachment inserted in the central incisor. Three aligners were manufactured for each of the three attachment designs, with 0.33-mm activation in the direction of the extrusion. An analytical device was used to evaluate the forces applied to the three axes by each aligner/attachment. The data were assessed by one-way ANOVA and Tukey's test ($\alpha = 0.05$).

Results: All of the studied attachment designs could satisfactorily perform the extrusion movement. However, force intensities were different in the three designs (design 1 = 2.5 N; design 2 = 2.2 N, and design 3 = 1.1 N). Furthermore, two of the three attachment designs (designs 1 and 2) eventually exerted significant forces on the X (mesiodistal) and Y (buccopalatal) axes.

Conclusion: The attachment design 3 presents the best distribution of forces for extrusion movement, generating almost null forces on X and Y axes, and lower intensity of force on the Z axis.

Keywords: Orthodontic extrusion. Orthodontic appliances. Biomedical technology.

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INTRODUCTION

In recent years, the search for esthetic solutions by orthodontic patients has increased. Aiming to achieve a less invasive, more esthetic, hygienic, and comfortable orthodontic treatment, transparent and removable orthodontic aligners have increasingly become a popular alternative to conventional treatment with metallic brackets.[1-3]

Aligner therapy is based on the sequential use of aligners to gradually move the teeth to the desired position. The forces and moments required for malocclusion correction are generated by the difference between the shape of aligners and the teeth.[4,5] Scientific reports have demonstrated that extrusion movements with aligners are the most difficult ones;[6,7] therefore, the use of movement accessories such as attachments is indicated.[8]

Attachments are small structures with well-defined geometry used to generate forces or moments, increasing the capacity of orthodontic aligners to move the tooth[9,10]. Although attachments have great potential, their use in dental practice is restricted because just a few studies have evaluated its mechanical behaviour,[10-12] and there is a significant gap of information about the biomechanical performance of these accessories based on their size, geometry, and forces.[9,10] Although the study of Dasy et al.[11] observed higher retention force for beveled attachments than rectangular or ellipsoid ones, and Cai et al.[10] optimized an attachment for tooth translation, no study evaluated the efficacy of attachments for tooth extrusion.

Therefore, the present study aims to evaluate *in vitro* the forces generated on the X, Y, and Z axes, developed by different attachment designs, associated with orthodontic aligners during the extrusion movement of an maxillary central incisor. The study hypothesis is that changes in attachment design produce different loads on the tooth.

MATERIAL AND METHODS

Model preparation and dental software program

The maxillary model used as three-dimensional reference was obtained free of charge at Cadnav.com. The original model had 7,048 vertices, 14,028 triangles, and a file size of 908 kilobytes. The low-resolution mesh of this model would hinder its recognition by computer-aided design (CAD) software program, so the mesh was manipulated using Meshmixer (Autodesk, California, USA), and a more refined design was then obtained and recognized by the dental software (CAD/CAM OrthoAnalyzer 2013, 3Shape, Copenhagen, Denmark), which was used to simulate orthodontic movements.

The model was parameterized in the following stages: segmentation of the tooth and determination of the limit between tooth and gingiva; identification of the mesiodistal limit of each tooth; and determination of the long axis of the tooth. In the parameterized model, a 0.33-mm extrusion movement was simulated on the Z-axis of the right maxillary incisor, considering the Z axis to be equal to the long axis of the tooth.

Development and insertion of the attachments

Three attachment designs were developed using the Sketchup software (Trimble, California, USA), as shown in Figure 1. Although the designs were slightly based on the conventional rectangular, bevelled and ellipsoid conventional attachments, they represent a new geometry and concept, aiming to optimize attachments design for free of patents use. The marginal faces of attachments are larger than conventional models, increasing their prominence, and a retentive inclined plane in the vestibular face of the attachment was created to increase its active area.

The first attachment geometry (Figs 1A and 1B) consisted of a rectangle with $8\,mm^2$ on its gingival face and a 3-mm thickness from the dental surface to the frontal face, to provide aligner retention.

The second attachment geometry (Figs 1C and 1D) was designed for force application at 45º from the movement, thus facilitating aligner insertion. It was designed from a $2 x 4 x 1$ mm^3 cuboid, associated with two $0.87 x 4$ mm^2 rectangular planes angled at 45º with the cuboid surface.

The third attachment geometry (Figs 1E and 1F) presented a frontal face without edges and less protrusive, with a vestibular length of 3.32 mm. This geometry was presumably more comfortable than the others.

All the attachments were inserted in the central area of the right maxillary incisor using the mean point between the following guidelines: incisal edge, cementoenamel junction and the proximal contact points.

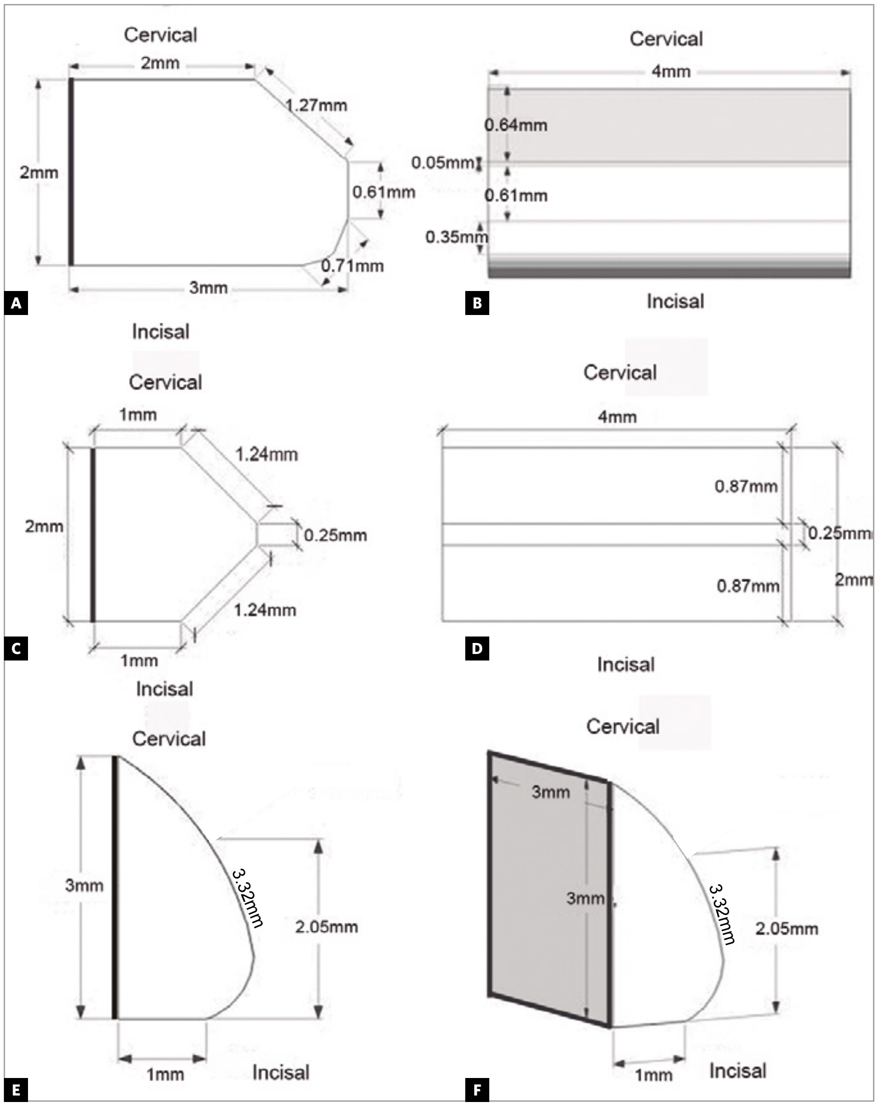

Figure 1 - Attachment 1 in lateral view (**A**) and frontal view (**B**). Attachment 2 in lateral view (**C**) and frontal view (**D**). Attachment 3 in lateral view (**E**) and isometric view (**F**).

Model prototype and aligner manufacture

The models were imported into the Meshmixer software to be prototyped. Two models were prototyped for each attachment. The first model (phase 0), with the teeth in the original position, was used to calibrate the device for force measurements in the initial position. The second model (phase 1) with a 0.33-mm extrusion of tooth #11 on the Z axis, was used to develop the aligner in which the forces would be measured. In both models, a cylindrical section was performed to allow the connection of tooth #11 to the device for force measurements (Fig 2C). The prototypes were printed in a 3D printer (model ZprinterProJet CJP360, 3Dsystems, Valencia, USA), with a resolution of 2 layers/min and interlayer resolution of 0.08 mm. It was used a monochromatic high-performance print material, composed by zp131 Powder (Z Corporation, Burlington, USA).

Aligners were made for each prototyped model using BioStar (Scheu, Iserlohn, Germany) with a positive pressure of 6 bar. Polyacetal DH aligner (Dhpro, Paraná, Brazil), with thickness 0.75 mm and d = 125 mm, was used to build the aligners. After acetate cooling, the edges of the aligner were cut with an HM carbide cutter (Scheu, Iserlohn, Germany) and polished with Finishing Set (Scheu, Iserlohn, Germany).

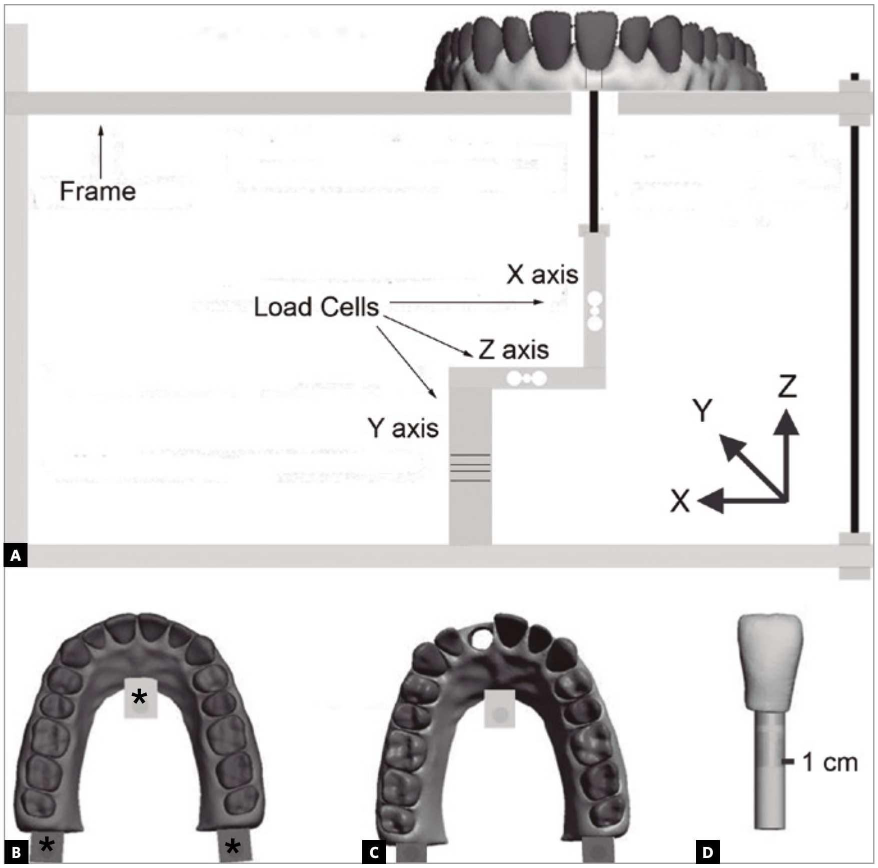

Figure 2 - A) Force measurement device, with three load cells coupled. B) Three points for model fixation in the device. C) Cylindrical cut for connection between the teeth and the device. D) Cylindrical shaft created in the central incisor.

Force measurements

Figure 2A shows a schematic view of the device used to measure the forces generated by the aligners. The device was specifically developed for the present study. Three one-dimensional load cells, with a capacity between 0.01 and 7.5 N and a precision of 0.01 N (Diamond, Hong Kong, China), calculated the load on the X, Y, and Z axes. The device was calibrated by weighing the aligners in each axis to verify whether only pure forces were measured, thus ensuring that torque would not affect the outcomes. A frame allowed the fixation and adjustment of the model, as well as the connection of the right central incisor to the measurement device, as shown in Figure 2. The model was screwed to the frame in three points, as highlighted in Figure 2B, and no movement of the model was observed during the test. Figure 3 shows the model fixed to the frame.

The maxillary central incisor, kept in position in the model, was connected to the measurement device through a metal rod abutment (Fig 2D). The metal rod was fixed in the maxillary central incisor using a ruler to maintain the vertical axis previously established, and it was fixed to the device with a screw nut. The difference between the cylindrical van in the model and the cylindrical rod of the upper central incisor was around 1 mm. With phase 0 aligner in position, the model position was adjusted until the load cells showed a load of zero, when the auto-zero function was activated.

Three aligners were fabricated for each attachment model. Each aligner was measured three times (27 measurements). The values obtained by the force measurement device are expressed in grams-force (gf) and were converted to Newton, multiplying it for 9.8. The resultant force and the angle of inclination (ω) of the resultant force on the Z axis were calculated according to the forces components observed in the three axes.

The data were checked for normality (Shapiro-Wilk test) and homoscedasticity (Bartlett's test), and assessed by one-way ANOVA and Tukey's test, with a 95% significance level (α=0.05).

Figure 3 - 3D-printed model, with thermoplastic aligner fixed in the frame.

RESULTS

Data on the forces generated on the X, Y, and Z axes and the resultant force are shown in Table 1. The X-axis represents the forces towards the mesial (positive) and distal (negative) direction of the tooth. Note that the assessed attachments showed significant differences between them: attachment 2 produced the lowest force and had the opposite direction, when compared to the other attachments.

The Y-axis represents the force towards the bucco-palatal direction, and it was positive for the buccal direction and negative for the palatal one. Forces in attachments 1 and 3 were towards the buccal direction and showed no statistically significant difference between them, but they both generated forces of significant lower intensity and inverse direction than did attachment 2, whose forces were towards the palatal direction.

The Z-axis represents the extrusion (positive) and intrusion (negative) movements of the tooth. As expected, the three attachments showed positive forces, with statistically significant differences in their intensity.

The three attachments revealed significant differences in the resultant force, as illustrated in Figure 4. Note that attachment 1 had the highest resultant force. The angles of inclination of the resultant force on the Z-axis are shown in Table 1. Attachment 1 had the lowest angular deviation from the Z-axis, and attachment 2 showed the highest angular deviation — these angular deviations were statistically different. However, when the resultants forces from the X and Y axes are observed, attachment 3 showed the significant lowest deviation from Z, whereas attachment 2 had the highest deviation.

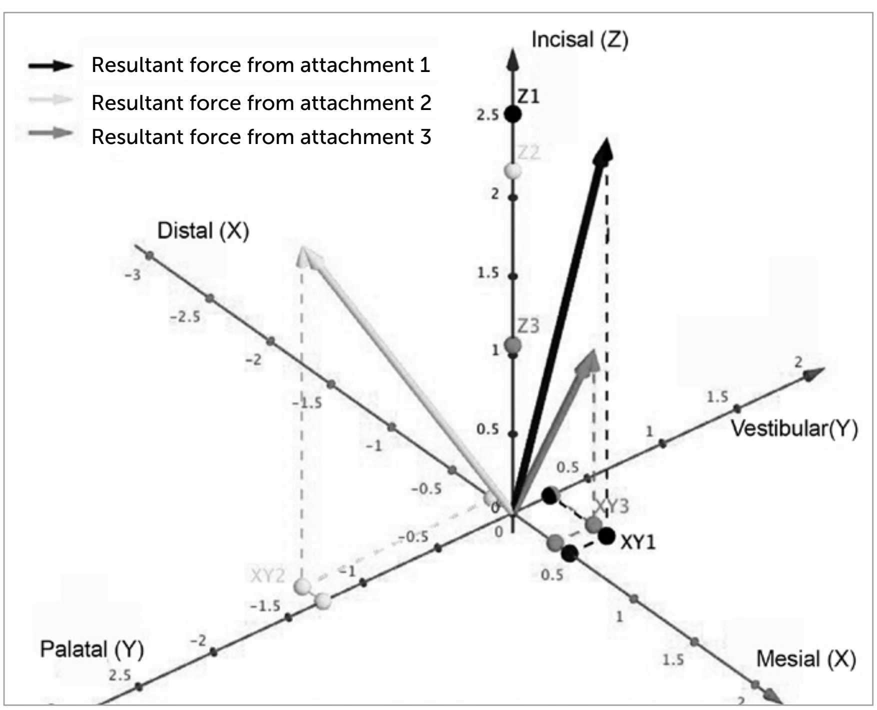

Figure 4 - Resultant forces analyzed on the, X, Y, and Z axes.

Table 1 - Mean and standard deviation of the forces (N) developed in the three axes (X, Y and Z), the resultant force from the 3 axes and from X and Y axes, and the angle of the resultant inclination, using orthodontic aligners associated to three attachments designs.

	Force (N)					Angle of the resultant inclination in Z axis (°)
	X axis	Y axis	Z axis	Resultant force from the 3 axes	Resultant force from X and Y axes	
Attachment 1	0.47 ± 0.06[a]	0.25 ± 0.02[b]	2.53 ± 0.02[a]	2.59 ± 0.01[a]	0.53 ± 0.04[b]	11.9 ± 1.1[c]
Attachment 2	-0.17 ± 0.02[c]	-1.27± 0.05[a]	2.17 ± 0.01[b]	2.52 ± 0.03[b]	1.28 ± 0.05[a]	30.6 ± 1.1[a]
Attachment 3	0.35 ± 0.01[b]	0.26 ± 0.03[b]	1.12 ± 0.01[c]	1.20 ± 0.01[c]	0.44 ± 0.01[b]	21.3 ± 0.2[b]

Similar superscript letters in one column indicate the absence of statistical differences ($\alpha = 0.05$).

DISCUSSION

Different attachment geometries provide different loadings on the maxillary central incisor, regarding the resultant force and forces on the Z and X axes. The forces generated on the Y axis were similar between attachment models 1 and 3. Among the three attachments, attachment 2 differed more sharply from the other two, not only in its force intensity on all axes, but also in its force direction on the X and Y axes. In fact, the plane designed to incline the force to 45º had an excessive effect.

On the X axis, attachment model 2 generated 0.17 N in the negative direction, which is not considered high enough to perform an orthodontic movement — the literature recommends that at least 0.35 N should be applied to perform this type of movement.[13] Conversely, attachments 1 and 3 showed forces in the distal direction with different intensities: attachment 1 exceeded the 0.35 N proposed in the literature, while attachment 3 generated exactly 0.35 N, being on the threshold of tooth movement. The presence of these mesiodistal forces can be attributed to jittering that could develop between the aligner and the attachment; differences in the number of teeth on which the aligner is supported on each side of the moved teeth; and morphological differences between the mesial and distal surfaces of the moved teeth.

Regarding the Y-axis, attachment 2 generated a negative force of 1.27 N, favouring palatal tooth movement. Even with the opposite force developed by the aligner, the high force magnitude on the Y-axis exceeded 0.35 N; which, according to the literature, would be enough for orthodontic movement. However, attachments 1 and 3 showed similar forces on the Y axis: 0.25 and 0.26 N, respectively, both in a positive direction and not able to promote tooth movement. It is believed that the force in attachment 2 was towards the palatal direction due to its pyramidal geometry. In this model, a force exerted on the Z-axis when applied to the plane at 45º from the movement direction can be decomposed into a force on the Y-axis, which would help explain the palatal direction of the forces generated in this attachment model. Another explanation is the plane inclined towards the incisal surface, which differs significantly from the other attachment designs and could develop intrusive forces, decreasing forces on the Z axis and increasing them on the Y-axis.

To develop an design for pure extrusion movement, the attachment should ideally generate null forces on the X and Y axes. None of the analyzed attachments was able to exercise null forces on any of the axes X and Y. The performance of attachment 3 was close to that, since its forces were not enough for tooth movement on the Y axis and similar to threshold forces on the X-axis, with the lowest resultant force on the X and Y axes, being the most promising design. Although showing higher angular deviation from the Z-axis than did attachment 1, this was mainly due to the lower intensity of the force on the Z axis, rather than the intensity of the other components of the resultant force. Although these attachments designs are unique and represent a new geometry and concept, aiming to optimize attachments design for use free of patents, to date, no studies have been conducted on attachment designs for extrusion movement with aligners in the maxillary central incisor, nor with the conventional attachment. Just one study has evaluated the attachment geometry for canine translation.[12] Hence, it is not possible to compare those attachment designs with the ones developed in this study, since the dental movements evaluated are different and it is necessary to optimize the attachment design for each dental movement.

Regarding the forces on the Z axis, attachment 1 had the highest force intensity, due to its rectangular face at an angle of 90° in the force direction and possibly due to its larger protuberance than the other attachments, allowing for a bigger contact area between the aligner and the attachment. Attachment 2, even at an angle of 45° with the Z axis, revealed an intermediary force, possibly because of its $1 x 4$ mm^2 rectangular face in the cervical area of the teeth (Fig 1C). For having a rounded geometry, with no edges, attachment 3 showed a smaller contact area with the Z axis, and generated a lower force on it, in addition to a lower inclination of the attachment on its cervical face, showing a more vertical shape, allowing force intensity to decrease on the Z axis. The analysis of retentive force of conventional aligners has pointed that the ellipsoid attachment presented lower retention than rectangular or bevelled designs,[11] which besides of geometric and size differences can be in accordance to the present study, where the rounded attachment (design 3) presented lower forces in Z axis.[11] There was no contact between the incisal edge and the aligner to perform an extrusion movement; so there was not a normal force (opposite to the movement) which opposed the extrusion movement. It is known in the literature that a minimum load of 0.35 N and maximum load of 0.6 N are needed for tooth extrusion, but the intensity varies according to root shape and size.[13] In this study, all attachments generated a force 3 to 7.5 times higher than the minimum threshold for extrusion movement, and 2 to 4 times higher than the maximum force. A limitation of this study concerns the fact that, in the tested model, all teeth, except for the right incisor, were fixed to each other and to the model. So, they exercised a rigid anchorage to move the right incisor, which could increase the forces on this tooth. However, in clinical situations, all teeth used to anchor the movement are free and the periodontal ligament can release part of the generated stress, and lower force intensity can be developed to extrude the tooth.

Furthermore, in the present study, the forces were measured immediately after aligner insertion, but it has been reported that significant stress relaxation is observed in the aligners in the first eight hours after instalation,[14] what would decrease the forces transferred to the tooth. However, more studies are needed to observe the behaviour of these aligners associated with the attachments over a long term. These higher forces should be viewed with caution, as excessive forces applied to orthodontic movement can cause injuries to the supportive tissues. Several studies have shown that orthodontic aligners promote root resorption that is similar to or lower than that generated by conventional brackets.[15,16] Hemanth et al.[17,18], using finite element method (FEM), observed that dental extrusion movement causes tensile stress in the dental apical area and compressive stress in the cervical portion of the root, which is in accordance to the system proposed by Proffit et al.[13] These effects may be maximized with the increase of forces generated during an orthodontic treatment; however, further studies are needed to evaluate these biological effects.

By analyzing the resultant force, one can observe that among the three assessed designs, attachment 3 is the one with the lowest force intensity on the X and Y axes, although the intensity is twice as high as the maximum load recommended in the literature, and its biological effects remain unknown. In addition to the mechanical aspects described, some other advantages include the rounded edges, as they help lower retention, facilitating aligner removal. Attachment 2 generated excessive force on the Y-axis; consequently, it cannot be indicated for pure extrusion movement, but its application could be investigated when the tooth also requires an inclination of the palatal plane. Finally, attachment 1 is similar to attachment 3 on the Y axis, with the lowest angular deviation from the resultant force, and exercises higher forces on the Z and X axes, which would be undesirable in clinical application.

Therefore, the results obtained in this study do not allow the direct indication of these attachments for immediate clinical use, but the proposed method is simple and promising for the biomechanical evaluation of attachments in orthodontic movements with aligners. A load cell, with a capacity between 0.01 and 7.5 N and a precision of 0.01 N, was used to build the measuring force device, its precision is higher than other orthodontic force tester describe in the literature,[19] and enough for evaluating orthodontic forces, being a simple tool to optimize attachments design. These results may contribute to scientific advances and knowledge of biomechanical attachments, leading to the optimization of new attachments and improving treatment predictability regarding extrusion movements.

CONCLUSION

Despite the limitation of this study, it may be concluded that: (1) different attachment geometries generate forces with significantly different intensity and direction; (2) attachment 3 had the best mechanical performance among the three models evaluated. Its force on the Z axis was enough for orthodontic extrusion and significantly lower than that of the other attachments, although the force intensity can still be considered high; forces on the Y axis are not enough for moving teeth and in X axis is on the threshold of tooth movement; (3) further studies are needed to improve attachment 3 design and to evaluate its biological effect on the supportive tissue.

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Orthodontic treatment of unilateral cleft lip and palate associated with maxillary canine/premolar transposition: case report

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Introduction: The cleft lip and palate is the most frequent craniofacial anomaly and as a consequence of this malformation some inadequate occlusal relationship between the arches are observed. Furthermore, dental absences, individual positioning changes of teeth as rotations, and in more rare situations the transpositions may be found as well.

Description: In this context, in this article is reported a case of a 9-year-old patient with unilateral cleft lip and palate, with anterior and posterior crossbite on the left side, absence of the maxillary left lateral incisor, and transposition of the maxillary left canine and first premolar. The patient was treated with slow maxillary expansion, secondary graft and fixed orthodontic appliance, transposition maintenance and closing of the lateral incisor space with the first premolar, by means of mesialization of the posterior teeth.

Results: At the end of the treatment, good intercuspation and an important aesthetic gain for the patient were achieved. The analysis three years after treatment revealed a good stability of the results obtained.

Keywords: Dental occlusion. Cleft lip. Orthodontic space closure.

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

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INTRODUCTION

The cleft lip and palate is a congenital malformation characterized by the absence of fusion of the palatine processes during the embryonic phase, with high prevalence, present in 1 in 1,100 births in the world, being the more frequent craniofacial anomaly.[1-6] Clinically the clefts are classified according to the incisive foramen, and divided into four types: pre-foramen clefts or lip cleft, post-foramen clefts or palate cleft, transforaminal cleft or cleft lip and palate, and the rare fissures of the face.[6] In addition, fissures can be found unilaterally, bilaterally or medial, with unilateral clefts being the most frequent.[2,7]

In the region of the cleft, it is common to observe problems of occlusal relationship such as posterior or anterior crossbite due to contraction of the upper arch, absence of permanent lateral incisor, rotations, changes of crown shape and, in some situations, the dental transpositions.[1,3,8-12]

The dental transposition is considered a subdivision of the ectopic eruption, and is an order or position disturb with prevalence of 0.4% in the population. However, its prevalence in patients with cleft lip and palate is considerably higher, around 14%.[11,13-15] It is characterized by the change of position of two adjacent teeth in the dental arch, in the same quadrant, and its etiology is still not fully understood: recent evidence points to multifactorial hereditary genetic influence due to the bilateral occurrence of the problem.[7,8,11,14,16] The transposition treatment is based primarily on the decision to accept or correct the transposition and based on that, depends on several factors such as occlusal relationship in the maxillary and mandibular arches, alveolar bone thickness, individual tooth positioning, age of the patient, inherent risks such as resorptions, gingival recession and fenestration, aesthetic characteristics of the smile, among others.[7,8,16,17] Furthermore, another important decision in cases of cleft lip and palate associated to lateral incisor absence is to keep the space for rehabilitation or close the space through the mesial movement of posterior teeth along the bone graft. This decision must be based on many factors as the age of the patient, occlusal relationship, bone condition, smile esthetics and mainly the long-term functional and esthetic result.[1,2,4-6]

Based on that, this manuscript presents a case of a patient with left unilateral transforaminal cleft, with anterior and posterior crossbite, lateral incisor absence and transposition between canine and first premolar. The patient was treated with slow maxillary expansion and orthodontic mechanics to close the spaces through the mesialization of the posterior teeth, accepting the transposition and positioning the upper left first premolar at the place of the absent left lateral incisor.

CASE REPORT

The patient, a 9-year-old boy, sought for treatment at the Foundation for Rehabilitation of Craniofacial Deformities (FUNDEF) in Lajeado (RS, Brazil), due to the presence of cleft lip and palate.

Diagnosis

In the analysis of the initial facial photographs, it was possible to verify that the patient had proportional facial thirds, passive lip seal, convex profile and discreet flattening of the left nostril and lip asymmetry on the left, as a result of the unilateral cleft and consequently of the primary surgeries of cheiloplasty and palatoplasty, which had been performed in the months following his birth (Fig 1). In the intraoral and dental casts analysis, it was verified a Class II molar relationship on both sides, absence of the left maxillary left lateral incisor, deviation of 2mm between the maxillary and mandibular midlines, with the maxillary midline matching the facial midline (Figs 2 and 3). In addition, clinically there was also anterior and posterior crossbite on the left side as a result of lack of transverse development of the maxillary arch in that region. Through the panoramic radiograph, the absence of the maxillary left lateral incisor was confirmed, all other permanent teeth were present, except for the germ of the tooth #28 and the complete transposition of the maxillary left canine with the first premolar was also identified in the same quadrant. Lateral cephalogram along with the cephalometric tracing showed a facial pattern with increased vertical growth, skeletal Class II, maxillary incisors uprighted and mandibular incisors proclined (Fig 4).

Figure 1 - Initial facial photographs.

Figure 2 - Initial intraoral photographs.

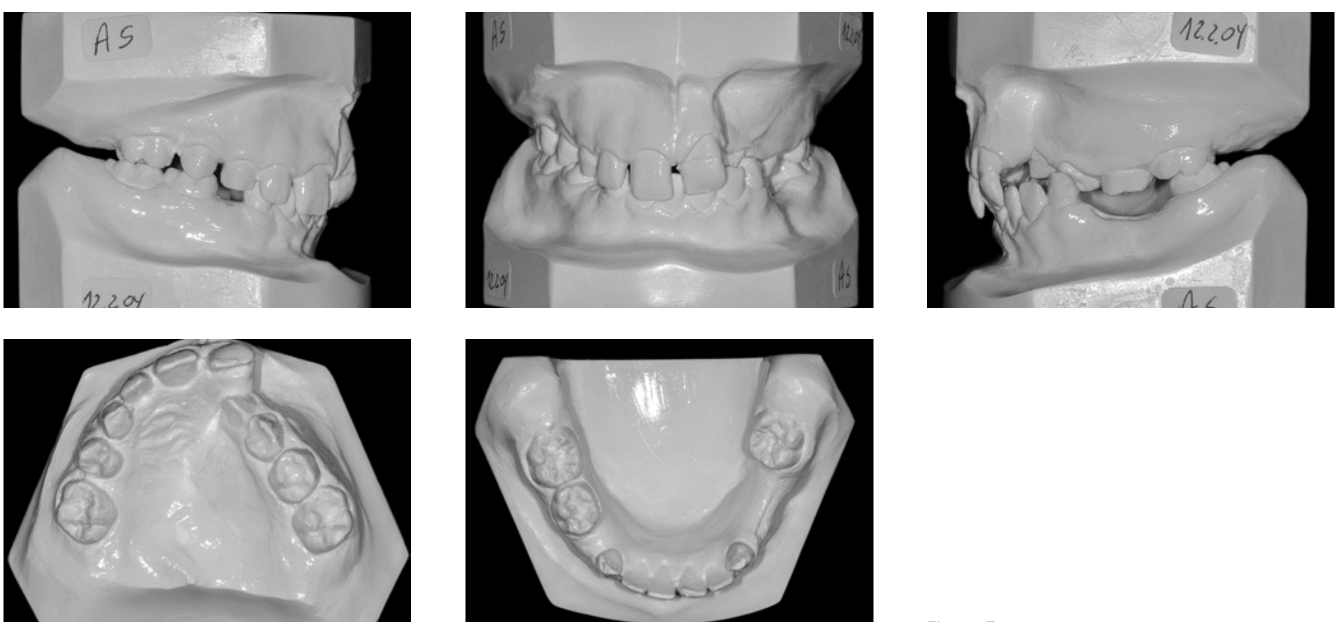

Figure 3 - Initial dental casts.

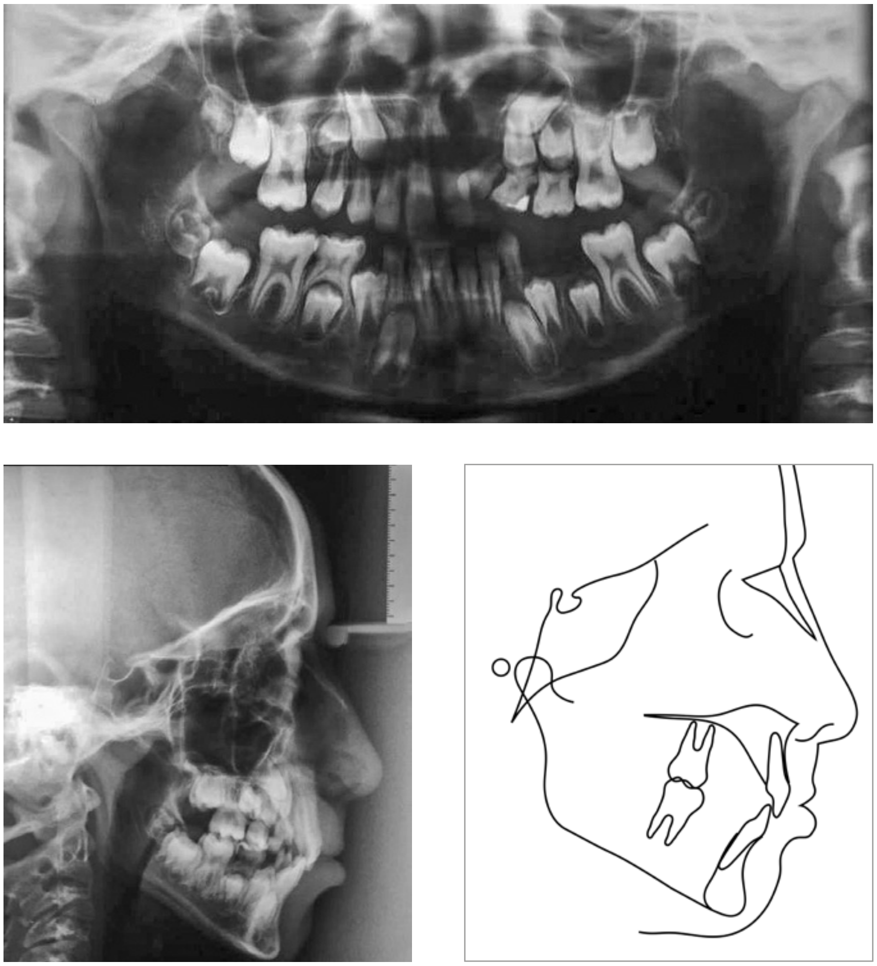

Figure 4 - Initial radiographies and cephalometric tracing.

Treatment objectives

The objectives of the treatment were to:

1. Correct the anterior and posterior crossbite.

2. Perform secondary alveolar bone grafting after slow maxillary expansion.

3. Accept transposition due to the risks of attempted correction

4. Close the space of the maxillary lateral incisor absence with the first premolar, through the mesialization of the posterior teeth.

5. Perform rehabilitation procedures on the anterior teeth after orthodontic treatment

Treatment plan

Initially, a slow maxillary expansion was planned to be performed with a fixed quadrihelix. After the end of the expansion, the autogenous secondary graft removed from the iliac crest would be performed and the upper and lower fixed orthodontic appliances would be bonded. After alignment and leveling, the right maxillary second premolar extraction would be done and a mini-implant would be installed in the maxillary left quadrant, to assist the anchorage in the mesialization of the posterior teeth of this side, to close the space of the absence of the maxillary left lateral incisor. In the finishing procedures, bending and rebondings would be planned to optimize the positioning of the maxillary anterior teeth and later the patient would be referred for aesthetic restorations.

Treatment alternative

The alternative considered for this case was the distalization of all teeth on the left side of the maxillary arch, thus opening space for rehabilitation. The main advantage of this option would be the reduction of the treatment time, because probably the distalization would be faster than the mesialization over the bone graft region. However, one important disadvantage would be bone graft condition and the aesthetic and functional result of the rehabilitation, because an implant would have doubtful success rate and longevity, and a conventional prosthesis would not maintain the amount and quality of the bone in long-term. Furthermore, the slow mesial movement of the posterior teeth would have a beneficial effect over the bone graft on that region.

Treatment progress

The treatment began at 10-years old with the installation of a quadrihelix appliance in the maxillary arch for slow expansion of the maxilla, with activation once a month, for 8 months. After expansion, the device was kept in position for another 12 months and during this period of retention, the patient was referred to perform a secondary autogenous graft from the iliac crest, performed by the FUNDEF team of surgeons, at the Bruno Born Hospital. At 12-years-old, 0.022 x 0.028-in Roth brackets were bonded, and the alignment and leveling was performed initially with round 0.012-in and 0.014-in NiTi wires, followed by 0.016-in to 0.020-in stainless steel archwires, and 0.018 x 0.025-in rectangular stainless steel archwires. The quadrihelix was kept in position during the first stage of alignment and leveling, and was replaced soon after by a transpalatal bar After alignment and leveling, the maxillary right second premolar was extracted and the space was almost totally occupied by the eruption of the first premolar on that region, leaving a small space to be closed by mesialization of the posterior teeth. To assist in the mesialization of the upper left posterior teeth, a mini-implant was installed between the roots of teeth #23 and #24. The mini-implant was connected to the second molar by 0.012-in braided metallic ligation and the teeth were mesialized individually, with open coils with light forces (around 60-80 g/f), initially positioned between the teeth #23 and #24, being transferred to distal after the closing of the anterior spaces. In the finishing phase, palatal torque and extrusion bend were performed on tooth #24, with the aim of hiding the root volume and moving the gingival contour in an incisal direction in this tooth, which was positioned in place of the lateral incisor. Furthermore, the buccal and lingual cusps were worn to allow the extrusion and to avoid interferences. After seven years of treatment (two years of expansion and retention + five years of corrective orthodontics) the appliance was debonded, and a 3 x 3 mandibular fixed retainer and maxillary removable wraparound were installed (Figs 5 to 9).

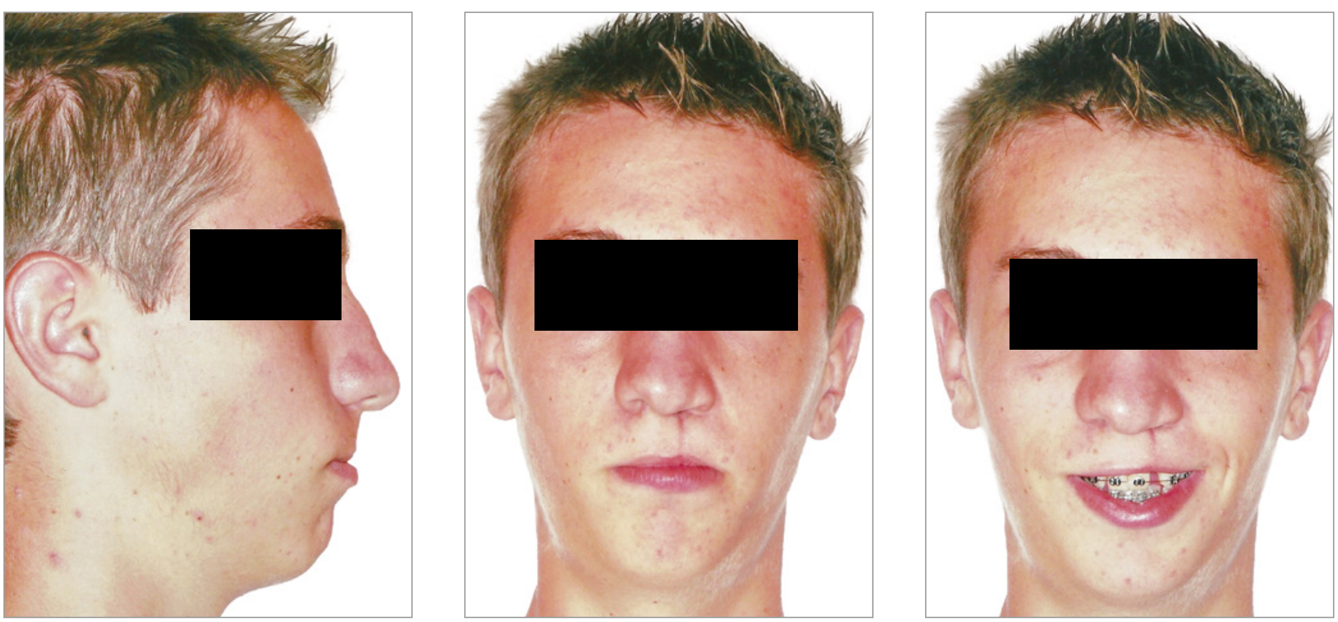

Figure 5 - Facial photographs during the progress of treatment.

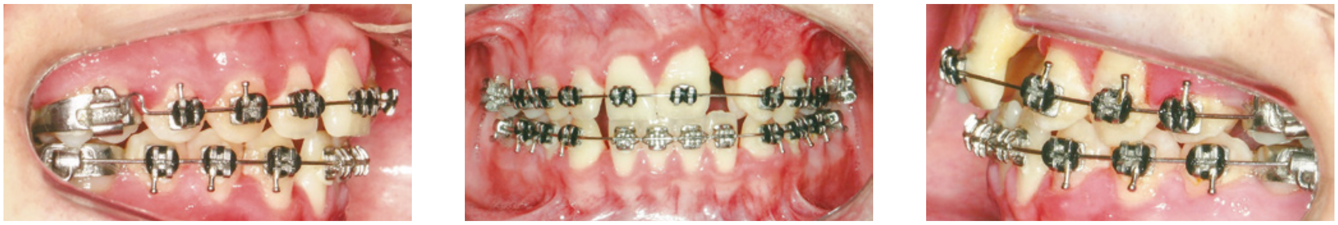

Figure 6 - Intraoral photographs during the progress of treatment, after the expansion with quadrihelix and in the beginning of the alignment and leveling.

Figure 7 - Intraoral photographs during the progress of treatment, after closing spaces on the left side of the maxillary arch. Mini-implant remained connected to the teeth, to keep the space closed.

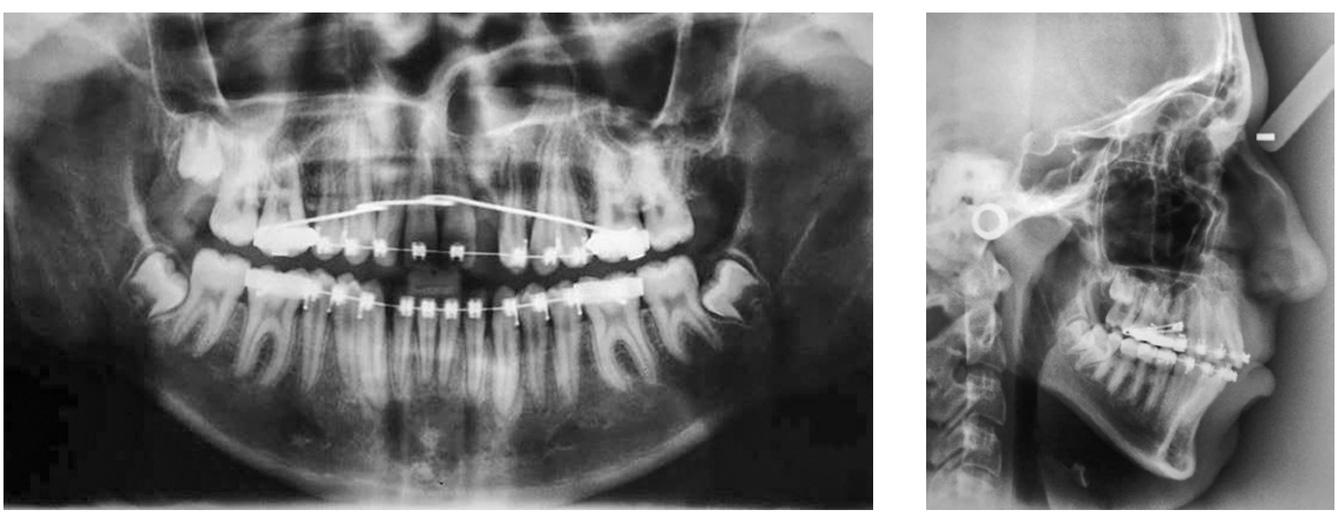

Figure 8 - Radiographies during the progress of treatment.

Treatment results

At the end of the treatment, it was possible to observe the preservation of the facial aspects, with a significant improvement in the aesthetics of the smile (Fig 10). In the intraoral analysis, it was verified that a coincidence was established between the midlines, molar Class II and canine Class I relationship were obtained, with good intercuspation, adequate overjet and overbite, and the space of the upper left lateral incisor was successfully closed by the premolar replacement, obtaining good aesthetics and adequate function by the anterior and lateral guidances (Figs 11 and 12). In the panoramic radiograph, a good root parallelism was evident, except for the tooth #14; moreover, a slightly root apical resorption in the maxillary and mandibular anterior teeth was observed. In the lateral cephalogram, cephalometric analysis and superimpositions, a small improvement in the anteroposterior skeletal pattern was observed, an small change in the maxillary and mandibular incisors position and accentuated molar mesialization on the maxillary arch (Fig 13 and Table 1). In the 3-year follow-up analysis, it was possible to verify that the results obtained were stable, with a good occlusal relationship and preservation of the health of the tissues (Fig 14).

Figure 9 - Posttreatment facial photographs.

Figure 10 - Posttreatment intraoral photographs.


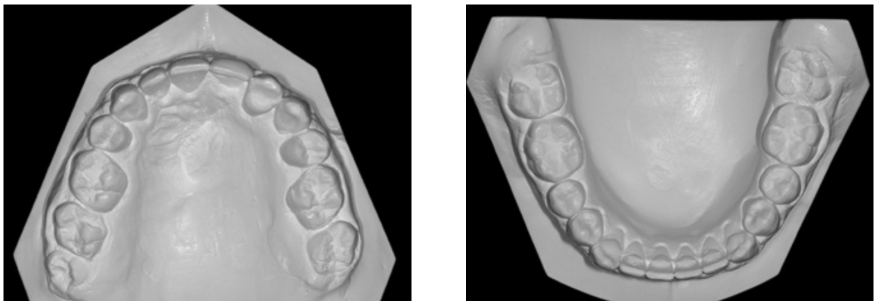

Figure 11 - Posttreatment dental casts.


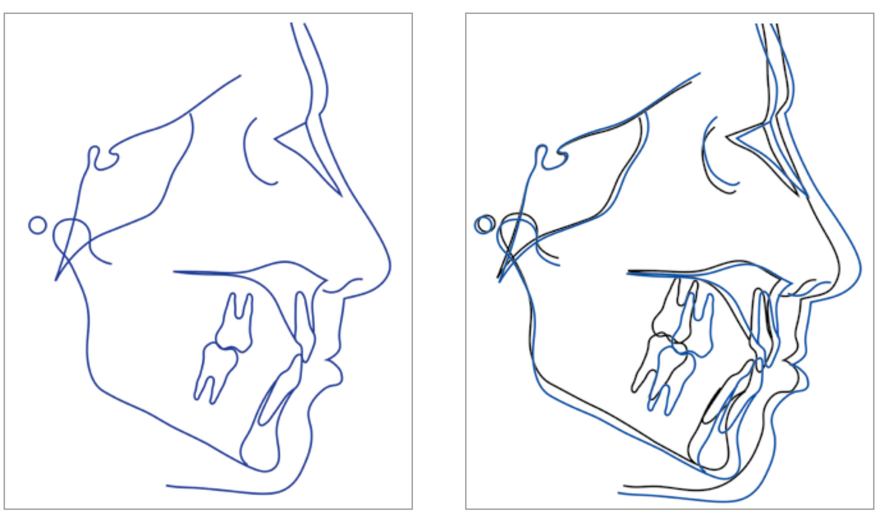

Figure 12 - Posttreatment radiographies, Posttreatment cephalometric tracing and total superimposition.

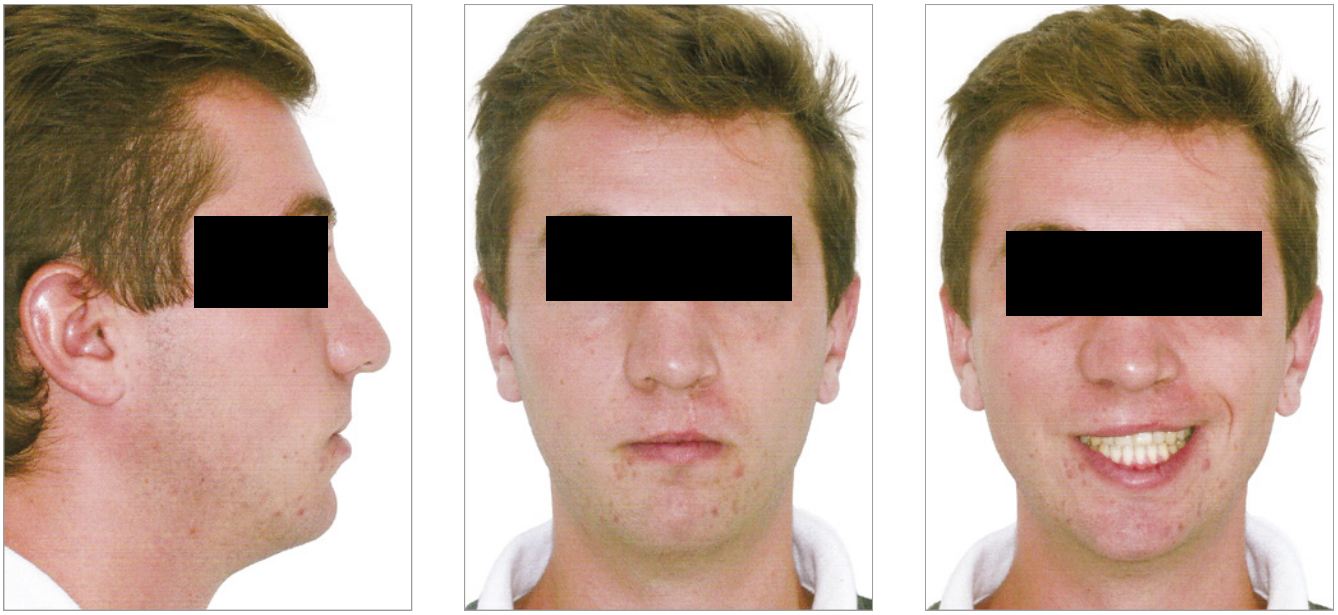

Figure 13 - 3-year follow-up facial photographs.

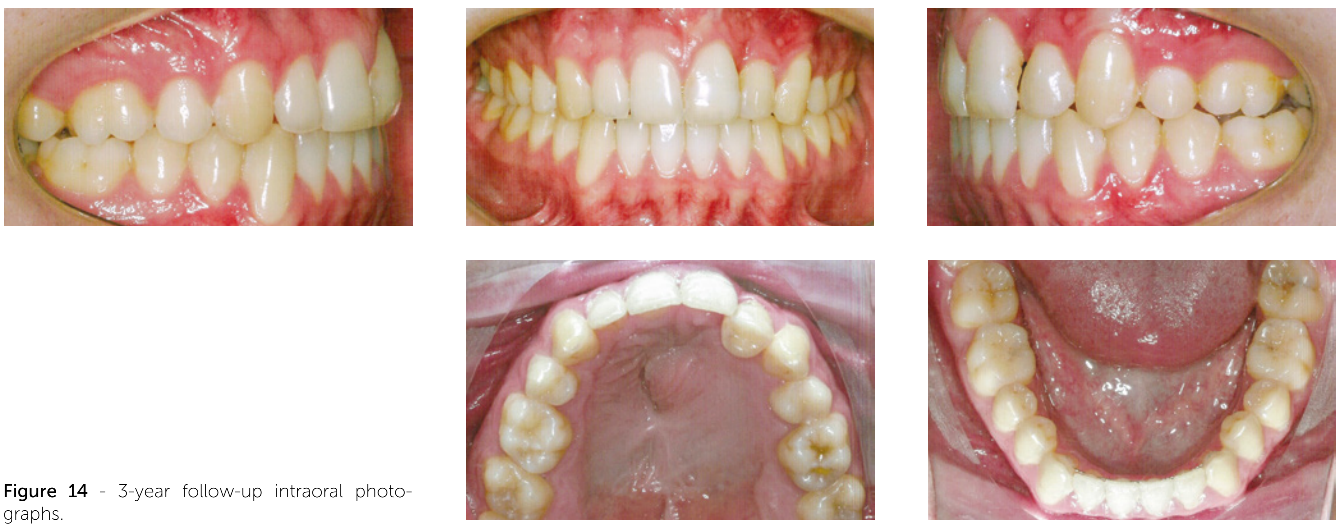

Figure 14 - 3-year follow-up intraoral photographs.

DISCUSSION

Patients with cleft lip and palate always represent a challenge for the orthodontist, due to the complexity of the mechanics involved in the correction of asymmetries, elimination of crossbite, correction of individual dental positions and closure of spaces of missing teeth. Absence of the lateral incisor is often associated with cleft lip and palate, and the orthodontist along with the rehabilitation team should define the best treatment option in this region.[1,2,4-6,18] Even after a successful secondary graft in the cleft region, there is a tendency to remain a vertical defect in this region, which in most situations contraindicates rehabilitation through implant and prosthesis.[2,5,19] In addition, implant and prosthesis rehabilitation in the long term tends to have a greater aesthetic compromise due to non-vertical physiological migration of the implant, which would imply the need for a new rehabilitation to

Table 1 - Cephalometric measurements.

Measurements	Normal	Initial	Posttreatment
SNA	82º	82º	80º
SNB	80º	72º	74º
ANB	2º	9º	6º
Facial convexity (NA.APog)	0º	17º	12º
Facial angle (PoOr.NPog)	87º	82º	84º
Y-axis	59º	64º	62º
SN.GoGn	32º	42º	40º
1.NA (degrees)	22º	1,5º	2º
1-NA (mm)	5mm	-4mm	-2mm
1.NB (degrees)	25º	30º	17º
1-NB (mm)	5mm	7mm	6mm
Interincisal angle	131º	141º	153º
UI-S line	0mm	0mm	-2mm
LI-S line	0mm	5mm	2mm
IMPA	90º	97º	85º
FMA	25º	32º	31º
FMIA	65º	51º	64º

restore vertical symmetry in this region.[5,19] Thus, two options are usually considered: space closure with orthodontic movement, or rehabilitation with conventional prostheses. When the secondary graft performed after the expansion provides a good amount of alveolar bone in the bucco-lingual and vertical direction, and the posterior teeth show adequate root condition, it is recommended to close the space, avoiding the necessity for rehabilitation at the end of the treatment, being necessary only an aesthetic adequacy of the anterior teeth that will occupy the space of adjacent absent teeth.[19] In the case reported, despite the presence of transposition, the posterior teeth showed adequate condition for the mesial movement and, in addition, excellent bone quantity and quality were obtained after the secondary graft, also favoring the closure of the space by orthodontic movement.

The decision to accept or correct a transposition is based on several factors, and must be made so that the benefits to the patient outweigh the harm.[7,8,11,17] The correction attempt should be made in adequate bucco-lingual thickness in the region, the integrity of periodontal tissue in the teeth involved, the presence of all teeth in the quadrant and also in situations of great aesthetic damage by transposition.[11,13-16,20] In the case presented, the patient already had lateral incisor absence in the maxillary left quadrant, associated with loss of bone tissue inherent to cleft lip and palate situations, so the attempt to correct the transposition could represent a risk of loss or impairment of one or more teeth during mechanics, increasing the aesthetic and functional impairment for the patient. In addition, from a functional point of view, with the acceptance of the transposition, a Class I canine relationship would be established. With the correction of the transposition, the premolar should perform the canine function, compromising the occlusal function. From an aesthetic standpoint, the transposition correction would take the canine to the lateral incisor site and the first premolar to the canine site, making it even more difficult to obtain adequate aesthetics in the anterior region.

Positioning of a premolar in the place of a upper lateral incisor may represent an aesthetic problem due to the difference in the shape of the crown between these two teeth, being the premolar more convex in the buccal surface and having more parallel mesial and distal surfaces between them.[1] This problem can be overcome with wear and/or restorations. In addition, the presence of the palatal cusp of the premolar may cause interference during the anterior and lateral guidance movements, and should be worn to avoid this contact.

Some limitations imposed by the occlusion and periodontal tissues of the cleft patients prevent better aesthetic and functional results and in shorter periods of time.[1] Usually these patients have little motivation and little collaboration with the treatment, with the use of elastics, hygiene and other necessary care with the appliance during the treatment.[5] However, even with these limitations, at the end of the treatment, adequate aesthetics and function were obtained and in the analysis three years after treatment it was possible to verify the stability of the obtained results.

CONCLUSION

Based on the literature review and on the results observed in the reported case, it is possible to affirm that the acceptance of the transposition of teeth in a region of cleft lip and palate is an adequate option from the standpoint of preservation of the teeth and periodontal tissues of the region, and allows to obtain good esthetic and functional results, even in long term.

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Complications encountered during Forsus Fatigue Resistant Device therapy

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Introduction: Fixed functional appliances are non-compliant solutions to Class II malocclusion treatment. The clinician, however, should be careful of unexpected complications during the therapy.

Methods: 58 female adolescents who presented with Class II malocclusion due to deficient mandible were treated with Forsus Fatigue Resistant Device (FFRD) therapy until an overcorrection to an edge to edge incisor relationship was achieved.

Results: Incisor relationship and overjet were corrected successfully in all the subjects. Twenty-two patients had a complications-free treatment, while several complications were encountered with the remaining 36 subjects. In particular, mandibular canine rotation and development of posterior crossbites were the most common complications, with percentages of 51.7% and 25.9% respectively. Other complications included the breakage and shearing of the extraoral tubes of the first molar bands, and excessive intrusion of the upper first molars.

Conclusions: FFRD is an efficient appliance for treatment of Class II malocclusion; however, different complications were encountered during the appliance therapy. A focus on taking precautions and applying preventive measures can help to avoid such problems, reducing the number of emergency appointments and enhancing the treatment experience with the appliance.

Keywords: Class II malocclusion. Forsus. Complication. Fixed functional appliance.

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INTRODUCTION

The benefits of orthodontic treatment include improvement in dental health, function, appearance, and self-esteem. Success of orthodontic treatment is affected by the discomfort caused by the appliances used. It is well documented that such discomfort might reduce the patients' compliance and satisfaction with the treatment.[1] Orthodontic appliances can cause unwanted complications, the presence of which may interfere with the treatment quality.[2] It is thus important for the clinicians to be aware of these potential complications before the start of orthodontic therapy.

Fixed functional appliances were introduced as compliance-free options for treatment of Class II malocclusion. The Forsus Fatigue Resistant Device[3] (FFRD) (3M Unitek, Monrovia, Calif, USA) was introduced after the earlier Forsus Flat Spring,[4] and was reported to be successful in the treatment of Class II malocclusion[5-7] and well accepted by the patients.[8-11] A recent systematic review investigated the prevalence of complications with fixed functional appliances, and stated that the incidence of complications is relatively high.[12] Studying the complications induced by orthodontic appliances has two main aspects: the clinician's observations and the patients' responses to assessment questionnaires. Regarding fixed functional appliances, the clinical perspective was previously reported with the Herbst appliance.[13-16] Previous studies that investigated the complications of FFRD were based on patient reporting and acceptance questionnaires.[8-11,17]

The present clinical report highlights several complications that were encountered during the FFRD therapy in adolescents with Class II malocclusion, and discusses how they were managed. These complications do not underestimate the efficiency nor the acceptability of the appliance. According to Benjamin Franklin axiom that "an ounce of prevention is worth a pound of cure", knowledge of such complications would be beneficial to the clinicians to take their safety measures during treatment.

MATERIAL AND METHODS

Fifty-eight adolescent females were consecutively treated, by the same clinician, with FFRD in the outpatient clinic of the Orthodontic Department, Faculty of Dentistry, Cairo University, in the period between 2013 and 2017. The clinician has been using FFRD for three years before this date. The patients' characteristics were:

- 11-13 years of age.
- Skeletal maturational stage was selected to be stage 3 or 4 from the cervical maturational index according to Baccetti et al.[18]
- Skeletal Class II malocclusion (ANB > 4°, as determined from pre-treatment cephalograms analysis).
- Deficient mandible (SNB < 76°, as reported from pre-treatment cephalograms).
- Class II canines' relationship and overjet ≥ 5 mm, as measured from pre-treatment study models.

Brackets with 0.022" slot (3M, MBT prescription) were bonded to maxillary and mandibular arches, and a transpalatal arch (TPA) was soldered to orthodontic bands that were cemented to the permanent maxillary first molars. TPA placement intended to control the molar rotation that might be induced by the distally applied force generated by the FFRD on the first molars.[19] The second permanent molars were not fully erupted in most of the patients at the start of treatment, and thus were not included in the initial leveling stage. Leveling and alignment proceeded until reaching 0.019 x 0.025-in stainless steel archwires, which were cinched distal to the first molars. The mandibular anterior teeth, canine to canine, were tied together with stainless steel ligatures. The mandibular canines were separately ligated with metal ligatures, for additional engagement during the FFRD stage.

The FFRD that was used in this report was the EZ2 module type. The proper size of the FFRD was selected according to the manufacturer instructions. The EZ2 modules of the springs were inserted in the extraoral tubes of the first molars and the push rods of the appliance were inserted distal to the mandibular canines. Patients were followed-up monthly, and activation of the appliance was done when necessary. Different complications that occurred during the therapy were reported and managed accordingly. Treatment was continued until an overcorrection to an edge to edge incisor relationship was achieved, and then the appliance was removed. The patients then continued their course of orthodontic treatment.

RESULTS

Baseline characteristics for the involved subjects are presented in Table 1. The duration of the FFRD phase was 5.82 ± 1.15 months. FFRD was successful in correction of the Class II incisor and molar relationship in all subjects; where an edge to edge relationship was achieved. Cephalometric and clinical results are to be published in a separate text.

Table 1 - Baseline characteristics of the included sample.

Age	12.4 ± 1.98
Overjet	6.17 ± 2.09
SNA	82.1 ± 2.33
SNB	74.9 ± 2.15
ANB	7.3 ± 1.88
MP/SN	35.7 ± 6.1
U1/PP	116 ± 4.53
L1/MP	97.8 ± 6.1

The encountered complications

Data of any clinical complications that occurred during treatment were collected from the patients' clinical records, which included pictures that were taken at the incidence of any complication. For the sake of simplification, these complications were summarized and subdivided into categories as presented in Table 2. The main categories were the complications related to problems in the FFRD and/or the fixed appliance; including breakage, separation of parts, spring fatigue and sheared molar tubes. The second category was concerned with the complications that were demonstrated in the patients' teeth and/or soft tissues; including swelling, rotated and/or intruded teeth and canting in the occlusal plane.

The current study reported twenty-two patients to have a complications-free treatment. In other words, 36/58 patients experienced various complications during the appliance therapy, with an incidence of 62%. This percentage is similar to the one reported by Phuong et al.[12] in their systematic review. The mean number of complications per patient was 1.4 when calculated over the whole sample. When the number of complications per patient was calculated over those who presented with complications, it increased to 2.25. Previous studies reported a range of 0.42 to 4.29 events per patient.[12]

Table 2 - The complications encountered during the FFRD therapy of the included patients.

Category	Complication	No of occurrence	Percentage of occurrence
A) Complications shown on the appliance	Breakage of FFRD (Fig 1)	2/58	3.4%
	Fatigue of FFRD springs (Fig 2)	4/58	6.9%
	Separation of parts "patients who were not able to reassemble the parts"	5/58	8.6%
	Shearing off the pre-welded extraoral tubes from the upper first molar bands (Fig 3)	12/58	20.9%
	Total number of events	**23**	
B) Complications demonstrated on the patients' teeth, intraoral and/or extraoral tissues	Extraoral swelling	3/58	5.2%
	Rotated lower canine(s)	30/58	51.7%
	Squeezing of the rotated lower canine(s) out of the arch (Fig 5A)	5/58	8.6%
	Increased upper molar intrusion and encroachment of the TPA on the palatal mucosa (Fig 6, 7)	4/58	6.9%
	Canting of the occlusal plane and a lateral open bite. (Fig 8A, B and C)	1/58	1.7%
	Development of posterior cross bite	15/58	25.9%
	Total number of events	**58**	
Total number of complications that occurred in the sample			n = 81
Mean number of complications per patient "in the whole sample"			n = 1.40
Mean number of complications per patient "in the patients who showed complications only from the sample (36 patients)"			n = 2.25

DISCUSSION

Reports on the complications of Herbst appliance and its variations are numerous in the literature.[13-16] All previous studies evaluating the treatment side effects of FFRD did not include clinical findings, but were based on patients' responses to pre-set questionnaires.[8-11] Unlikely, this clinical report showed the other perspective, that is, the clinician's observations. Assessment questionnaires are important to report patient acceptance and predict the expected level of compliance. However, they might have some disadvantages, for example, there is no way to tell how truthful a respondent is being, and there is also no way of assessment of the level of comprehension of the respondent to the questions. Moreover, subjectivity is always present because of the difference in perception between different respondents, and finally a risk of bias may exist when the researcher develops the questionnaire.[20] Clinicians' reports of complications are thus important to augment findings of different questionnaires of patients' acceptance to various appliances.

One of the factors that were accounted for in the current study was the level of clinician experience with the appliance. The cases of this clinical report were treated in a university setting and by the same clinician, who had been using the appliance three years before commencing the trial. It is believed that the level of operator experience with the appliance can affect the treatment progress, the incidence of complications and the overall patient experience. Lack of experience can account for multiple appliance breakages, failures and other complications. Bowman et al.,[8] who reported on the patient experience with FFRD, mentioned that the doctor experience level could be considered a confounding factor in their study. The formerly mentioned study[8] included a university clinic and private practice practitioners with varied levels of experience, which could have accounted for their higher reported breakage rates of the appliance. They recommended that further investigations should control the operator experience on examining the performance of the FFRD.

A) Complications in the appliance

FFRD breakage was encountered in this report in only two subjects. The first breakage was at the clip module of the spring, while the second was at the spring itself (Fig 1). Both appliances were replaced with new ones. FFRD breakage was reported to be higher in previous studies[6,8]; however, no data were given regarding whether the appliance itself or the orthodontic bands and/or wires were the broken parts. This could be an indication that FFRD might have less breakage rates when compared to the acrylic splint Herbst.[14,16] However, it should be kept in mind that the reported treatment duration of the Herbst appliance ranged from 8 to 12 months,[21] which is more than that for the FFRD. This longer duration can be the reason for the increased breakage incidence of the Herbst, as compared with the FFRD.

Although named FFRD, fatigue of the spring did occur unilaterally in four subjects of this report. The spring coils were uneven, and its springiness was markedly affected (Fig 2). Such an occurrence could be a result of over-activation of the appliance, which is a clinician-related problem.

One of the main advantages of the FFRD is that the patients can reassemble the parts through wide mouth opening with compression of the spring to embrace the push rod. Only five patients were unable to reassemble the appliances' parts on their own and they were educated to manage such an incident.

Shearing off the pre-welded extraoral tubes from the upper first molar bands was a common complication in the current report (Fig 3). It was accompanied with breakage of the molar bands in three subjects. This breakage was previously reported by Ross et al.[22] to occur in one out of 17 FFRDs. Management of such an occurrence was by removal of FFRD, the TPA and the maxillary archwire, followed by construction of a new TPA with new molar bands. After cementation of the new TPA, FFRD was re-inserted and treatment was resumed.

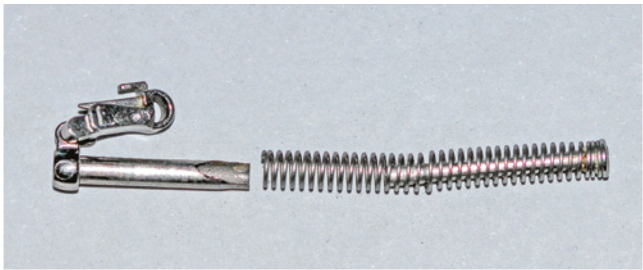

Figure 1 - A broken FFRD spring.

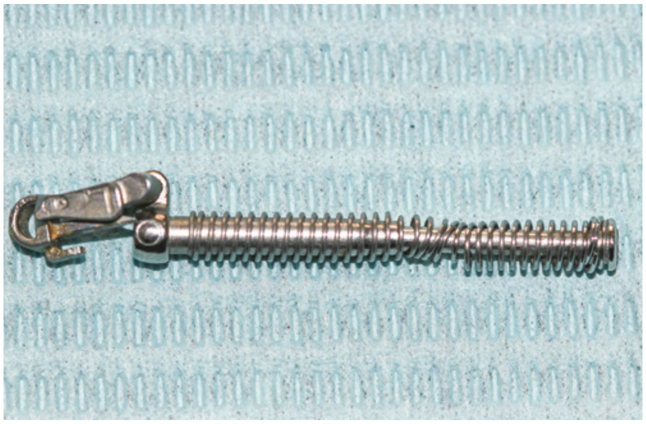

Figure 2 - Fatigued spring of FFRD.

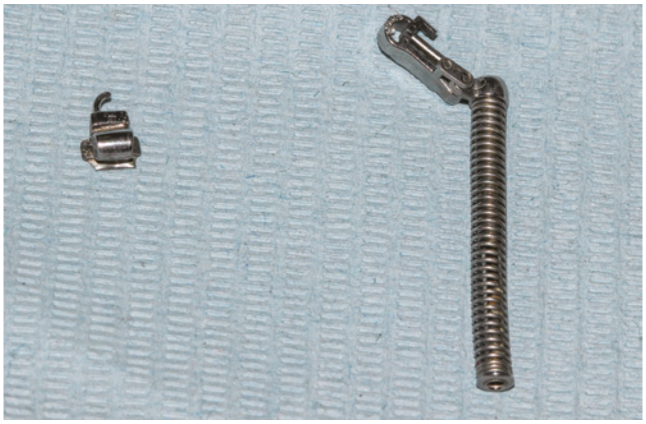

Figure 3 - Sheared off pre-welded extraoral tube from a maxillary first molar band.

B) Complications demonstrated on the patients' teeth, intraoral and/or extraoral tissues

Extraoral swelling, that was coupled with poor oral hygiene and cheek ulceration (Fig 4), was one of the severe complications of the appliance. Cheek irritation was in accordance with the previous studies evaluating the patients' experience with FFRD,[8,10] but the extraoral swelling was not previously reported. Appliances were removed, and the patients were referred for periodontal and surgical consultation. Recurrence of the condition did not occur, which is in accordance with previous reports that the discomfort associated with FFRD usually diminished with time.[9]

Rotation of the lower canines is a common occurrence with FFRD therapy due to the continuous forces exerted by the push rods.[23] It occurred in 30 cases in the current report. The severe rotation of the canine could be due to the gradual looseness of the canine ligation leading to mesial-in rotation caused by the continuous mesial force application to the canine bracket level buccal to its center of resistance. However, severe rotation that led to squeezing of the mandibular canine(s) out of the arch occurred unilaterally in five out of the 58 treated patients. Mesio-lingual canine rotation was managed by removal of the appliance and attempting to bring the canine back into the arch using elastic chains attached to a button bonded on the tooth lingual surface, pulling it towards the same rigid archwire (Fig 5B). After re-aligning the lower canines, treatment was resumed with re-insertion of the appliance.

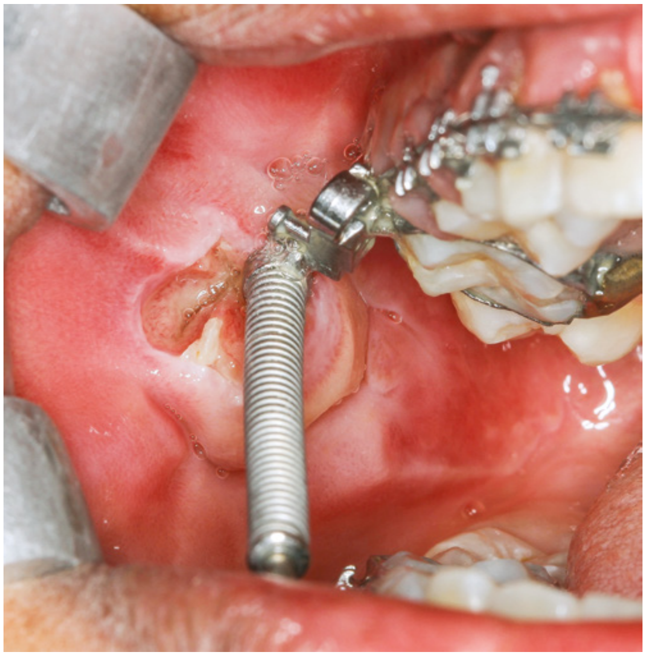

Figure 4 - Intraoral view of ulcers related to the FFRD.

Intrusion of upper first molars was reported as one of the treatment effects with FFRD,[24,25] and occurred in all the patients in this report. However, a considerable step between the upper first and second molars was evident in four of our patients (Fig 6) and a lateral open bite was developed accordingly. One reason for this could be that the second molars were not bonded and not leveled with the maxillary wires. The exaggerated intrusion also led to encroachment of the TPA on the palatal mucosa causing its inflammation (Fig 7).

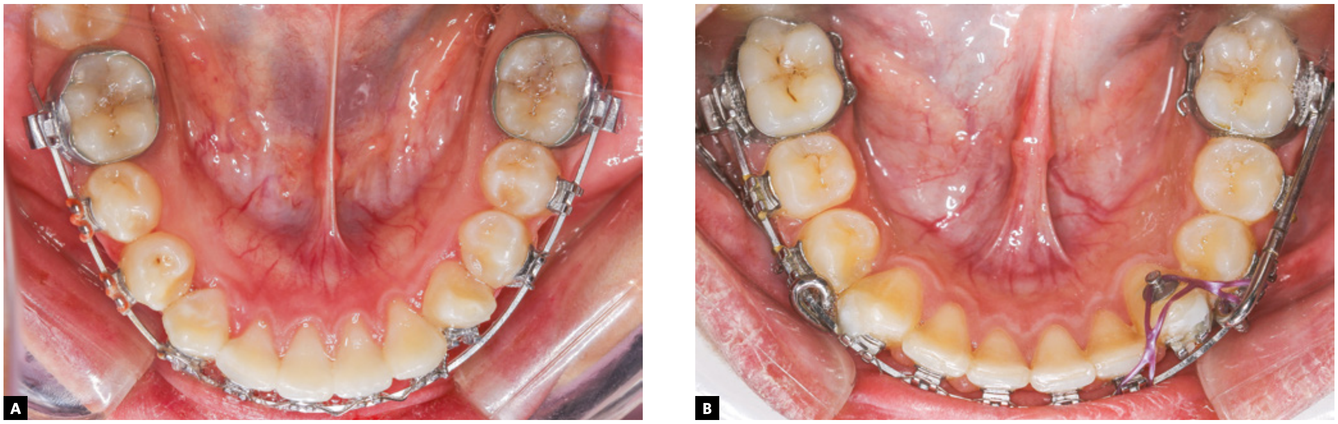

Figure 5 - A) Severe mesio-lingual rotation of the mandibular left canine. B) Procedures done for re-alignment of the rotated mandibular canine.

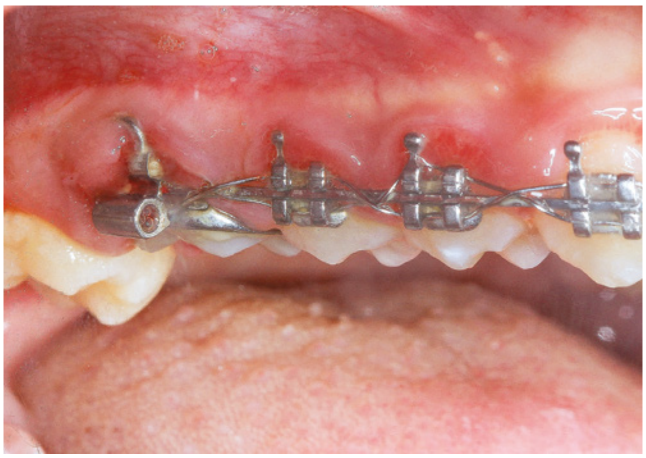

Figure 6 - A vertical step between the intruded maxillary buccal segment and the unengaged second molar.

Figure 7 - Encroachment of the TPA on the palatal mucosa.

One of the findings that require further investigation is the difference in the amount of intrusion in different patients. It is believed that the FFRD delivers disto-gingival forces towards the maxillary molars. Upon resolution of these forces, the vertical and horizontal components are present and are inversely proportional to each other. As the horizontal component was reduced, the vertical component of force could be exaggerated. The horizontal component is related to the sagittal distance between the maxillary first molars and the mandibular canines (the length of the appliance).

Missing appointments is a major cause of detrimental side effects of the orthodontic appliances.[26] One of the patients included in this report presented with a combination of complications including canting of the lower arch, a lateral open bite on one side, a missing FFRD spring on the opposite side and broken maxillary molar bands on both sides (Fig 8). This patient did not show for three months in a row before she presented with this clinical picture.

The occurrence of posterior crossbite during functional appliance therapy was previously reported in the literature because a wider posterior portion of the mandibular arch articulates in a forward position, with a narrower portion of the maxillary arch. Subsequently, it was advised to incorporate expansion screws in removable functional appliances.[27] This side effect was managed by expansion of the TPA after the end of the FFRD phase, together with coordination of the archwires.

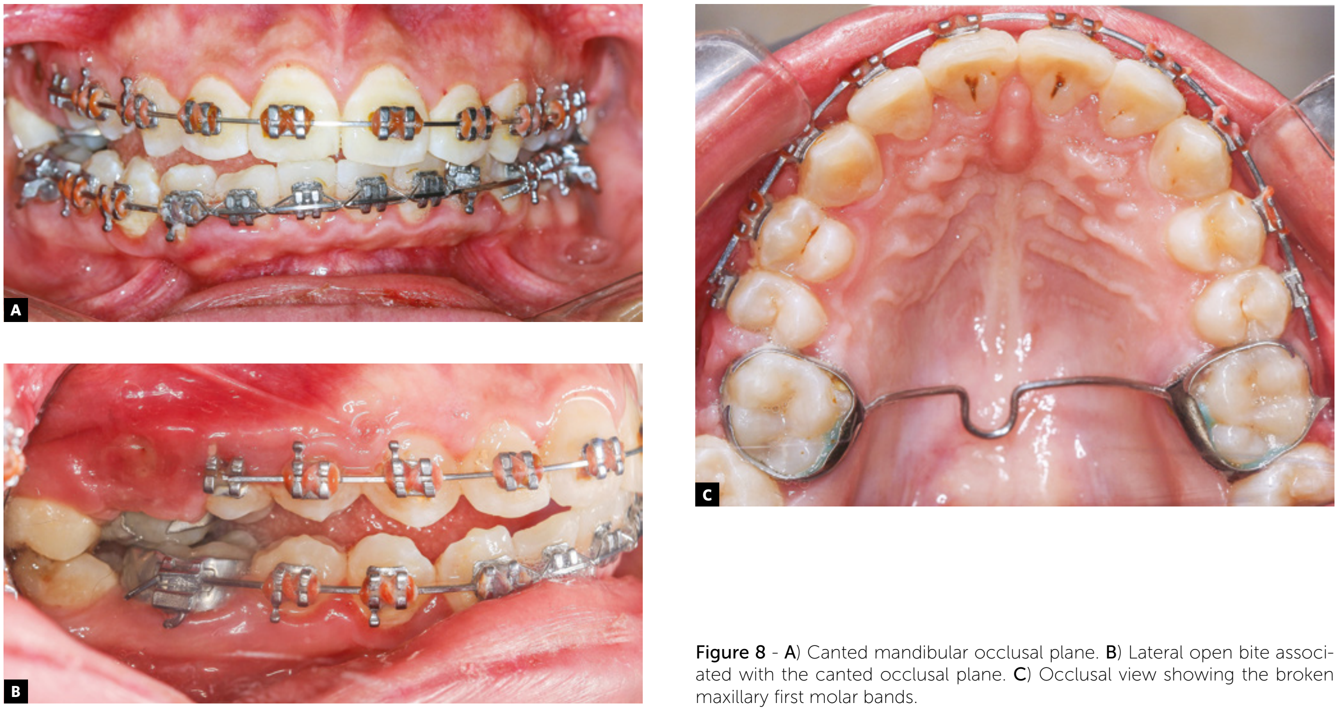

Figure 8 - A) Canted mandibular occlusal plane. B) Lateral open bite associated with the canted occlusal plane. C) Occlusal view showing the broken maxillary first molar bands.

To our knowledge, this is considered the first clinical report to document the clinical complications faced during the FFRD therapy and how they were managed. Consequently, several preventive measures are presented to avoid such complications:

a) Proper patient education is mandatory before the start of the FFRD therapy. This should include instructions regarding a strict oral hygiene protocol, limitation of excessive lateral movements and wide mouth opening, to avoid separation of the appliance parts.
b) Avoid over-activation of the appliance. This could help to avoid breakage of the appliance and/or the molar bands and, thus, reduce the number of emergency appointments.
c) Proper ligation of the mandibular canines is required to avoid their excessive rotation and squeezing out of the arch. Other measures can help reduce this complication including the use of elastomeric ligatures with a bite guard (3M Unitek, Monrovia, CA, USA) and/or rotational wedges.[23]
d) Proper selection of the size of the FFRD is needed to avoid the excessive vertical component of force, which results in exaggerated molar intrusion.
e) Second molars need to be included and levelled in the maxillary arch before the start of FFRD therapy. This can help avoid the excessive first molar intrusion during the FFRD stage.
f) The TPA is to be fabricated with 1-2 mm relief from the palatal mucosa. Slight expansion of the TPA could be helpful to avoid crossbites.
g) Cheek irritation that is caused by FFRD should be addressed, since it is a commonly reported event. Recently, spring caps have been introduced to cover the anterior and/or the posterior end of the spring, which may be the reason of cheek and/or lower lip irritation.

LIMITATIONS

The recruited sample included only females, which could have limited the generalizability of the study. Further studies are needed to compare between the complications induced by different appliances while recruiting bigger sample sizes.

CONCLUSIONS

Different complications were encountered during the FFRD appliance therapy and were reported hereby. This report could help to undertake preventive measures for avoiding the occurrence of such incidences.

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Surgically-assisted rapid maxillary expansion (SARME): indications, planning and treatment of severe maxillary deficiency in an adult patient

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Introduction: Maxillary deficiency, also called transverse deficiency of the maxilla, may be associated with posterior crossbite, as well as with other functional changes, particularly respiratory. In adult patients, because of bone maturation and the midpalatal suture fusion, rapid maxillary expansion has to be combined with a previous surgical procedure to release the areas of resistance of the maxilla. This procedure is known as surgically-assisted rapid maxillary expansion (SARME). **Objective:** This study discusses the indications, characteristics and effects of SARME, and presents a clinical case of transverse and sagittal skeletal maxillary discrepancy treated using SARME and orthodontic camouflage.

Keywords: Maxillary deficiency. Rapid maxillary expansion. Surgical expansion.

INTRODUCTION

Posterior crossbite (PCB) is characterized by posterior maxillary teeth positioned lingually in relation to posterior mandibular teeth, and a maxillary arch more constricted than one or both sides of the mandibular arch.[1] In skeletal posterior crossbite, the maxillary bone is transversally narrower than the mandibular bone, which characterizes maxillary atresia, also called transverse maxillary deficiency. Its correction requires orthopedic expansion,[2] known as rapid maxillary expansion (RME).

In adult patients, it is often necessary to combine surgical and orthodontic treatments to correct posterior crossbite in a safe, efficient and predictable way.[1,3]

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

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Factors such as ossification of the midpalatal suture (MPS) and the structure of the zygomatic buttress prevent expansion because of increased bone resistance.[4,5] The integration between orthodontics and surgery in the treatment of maxillary atresia is called surgically-assisted rapid maxillary expansion (SARME)[6].

SARME is a reliable procedure for the orthodontic treatment of adult patients when it is necessary to expand the maxilla.[5-8] Several surgical techniques to release the areas of resistance of the maxilla together with conservative procedures and with stable results have been described in the literature.[2,5,6] All the approaches include the previous placement of a fixed expander to open the MPS after surgery. Expanders may be tooth-borne, such as Hyrax, with[9] or without[10-12] an acrylic splint; tissue-tooth-borne, as the one described by Haas[13]; or bone-borne, using temporary skeletal anchorage devices that have been recently described, known as miniscrew-assisted rapid palatal expanders (MARPE).[14-19] Tissue-tooth-borne expanders often lead to inflammation and ulcerations in the palatal mucosa, which makes hygiene more difficult.[15] Comfort, easy placement and hygiene of tooth-borne expanders without an acrylic splint make them the most often used appliances, despite the fact that they apply lateral forces to the posterior teeth and alveolar bone. As they are placed away from the center of resistance of the maxilla, they produce a lateral inclination of the maxilla instead of a parallel expansion.[5] In contrast, bone-borne expanders, directly placed on the bone using mini-implants, apply lateral forces directly to the bone, which has better biomechanical results and reduces tooth and alveolar inclination.[5,15] However, Bortolotti et al.[8] conducted a systematic review and found that there is no difference in how much expansion is achieved after SARME using tooth-borne or bone-borne expanders.

SARME is indicated in the following cases: orthopedic expansion fails or cannot be used; genuine unilateral posterior crossbite; patients with complications during purely orthopedic expansion, such as intense pain, edema and palatal lesions; craniosynostosis syndrome, in which there is premature suture fusion; preparation for orthognathic surgery to achieve dental decompensation or to promote or increase stability in cases of large (more than 7 mm) dentofacial anomalies; and absolute maxillary transverse deficiency associated with deficiency of dental arch perimeter in adults.[6]

In addition to occlusal corrections, particularly that of posterior crossbite, maxillary expansion also improves nasal breathing, because it enlarges nasal volume, lowers the palate and reduces nasal resistance.[20-24] Magnusson et al.[25] found that patients that underwent SARME had anterior and inferior displacement, as well as widening of the nasal soft tissues, according to CT scans.

This surgical procedure is usually conducted in a hospital, under general anesthesia, particularly when pterygomaxillary separation is necessary, because of the risk of hemorrhage due to internal maxillary artery lesion. However, it may also be performed in the office, under local anesthesia[2,4,9] and/or sedation.[12]

Clinical cases with a thin alveolar bone between the roots of maxillary central incisors should undergo orthodontic root separation three to four months before surgery, to minimize the risk of osteotomies between roots causing asymmetric fractures in palatal suture, as well as in the alveolar bone and alveolar crest between incisors. Asymmetrical rupture of the palatal suture may result in bone defects, gingival recession with loss of interdental papillae, loss of pulp vitality, mobility or even loss of maxillary central incisor, postoperative infection, flap dehiscence and external root resorption.[6,26] In cases of periodontal diseases, activations should be discontinued until tissues heal.[26] Adequate clinical and radiographic evaluation should be conducted during surgical planning for SARME, to avoid these postoperative complications.[6]

Several postoperative expander activation protocols are found in the literature. Activation may start immediately after surgery,[9,12] or after a healing period, which ranges from three to seven days.[2,7,10,11] Activation of a ¼ turn (0.2 to 0.25 mm) twice a day until overcorrection is the most recommended protocol.[2,9-12] Oliveira et al.[26] recommended a two-turn activation protocol immediately after surgery until a characteristic ischemia of the palatal mucosa and a midline diastema were observed. After three days without any activation, the screw should be activated 2/4 of a turn in the morning and again in the evening, that is, one full turn a day, until the desired result is achieved. In any case, the orthodontist should monitor progression frequently and give instructions about activations to the patient.[26] After activations, the appliance should be stabilized and kept in that position as a retainer from 90 days[9,10,12] to six months.[7,11,27] Gurgel et al.[28] found that MPS ossification was not complete up to 120 days after surgery, and optical density on digitalized occlusal radiographs of adult patients that underwent SARME was not restored. At seven months after SARME, MPS density stills has only 50% to 75% of pre-treatment values on CT scans.[14] A transpalatal arch used for retention after SARME also does not improve dentoskeletal stability[29].

SARME effects include an increase in maxillary alveolar width and maxillary intercanine and intermolar disatances;[3,5,11,22] correction of posterior crossbite; reduction of palate height; significant increase in palate width;[3] and increased maxillary arch perimeter[11] and length.[11,22]

Expansion overcorrection is recommended, because some skeletal and dentoalveolar relapse may be expected, particularly in intercanine distances.[4,5,9,12,22,30] In contrast, Chamberland and Proffit[27] found that skeletal changes after SARME are stable, and relapse is mostly due to the lingual movement of maxillary first molars.

Massulo et al.[10] evaluated patients that underwent SARME immediately after stabilization and at three months of retention, and found a significant downward displacement of the posterior maxillary area and a downward and backward mandibular rotation, as well as a tendency to return to initial position, and a lingual tipping of maxillary central incisors. There was also some slight mesiobuccal rotation and significant buccal tipping of maxillary premolars and molars used as anchorage for the expander.[30] Byloff and Mossaz[7] confirmed SARME promotes minimal skeletal expansion by rotation, and what in fact occurs is the lateral rotation of the two maxillary halves due to the bone and dental tipping, which are responsible for part of relapse during retention and post-retention. In a recent systematic review, Bortolotti et al.[8] found that, although SARME is efficient to obtain expansion of the transverse dimension of the maxilla, its immediate effect results primarily from dental expansion in the molar region, and not exclusively from the transverse maxillary bone increase.

There were no negative clinical effects on the periodontium according to CBCT scans in the study by Gauthier et al.[31] Six months after SARME, they found a reduction in buccal alveolar bone thickness and an increase in the lingual alveolar bone thickness of most teeth, a reduction of buccal alveolar crest of canine and posterior teeth, and a tendency to reduction of the mesial interproximal alveolar crest in central incisors.

Several authors[4,9,21,22] reported that there is no difference between patient response to RME or SARME. Indications for each procedure should be based on patient age and, above all, on their skeletal maturation.

Janson and Silva Neto[15] recommended RME for adult patients using expanders, but no surgery, based on studies that revealed a large variation in MPS fusion according to patient age.[32,33] The results of this procedure are not predictable or stable, and the opening of the MPS[3,4,9] may fail, with dental or alveolar tipping in association with little or no basal skeletal movement[9]. Activation is slower, twice a week at the most, or as much as pain allows, which may extend activation time in up to two months.[34] The increase of the clinical crown of posterior teeth,[3] severe pain, periodontal complications, gingival recessions,[4,9] soft tissue necrosis, tipping and extrusion of maxillary teeth, alveolar bone tipping and uncontrolled relapse[9] may be undesired results in these cases. In adult patients, the long-term clinical significance of maxillary expansion without surgery is uncertain and questionable[35]. However, higher costs, discomfort and risks associated with SARME, in addition to patient reluctance to accept it, have led to the development of other treatment alternatives.[15,34]

The present study describes and discusses the main aspects of SARME and illustrates them with a clinical case of an adult patient with severe maxillary deficiency, bilateral posterior crossbite and Class III skeletal and dental malocclusion. This case was presented to the Brazilian Board of Orthodontics and Facial Orthopedics (BBO).

CASE REPORT

A 53-year-old male patient sought orthodontic treatment because he often bit his mucosa when chewing certain foods. At the time, he made it clear that he would not want to undergo surgeries or extractions, and that treatment involving two-stage surgery had already been offered to him by another dentist. His general health was good, he was allergic to sulfonamide and insect bites, and reported having undergone tonsillectomy at the age of 18 years.

Facial analysis revealed an increase in LAFH, a dolichofacial pattern, poor lip seal, concave profile, maxillary deficiency, mandibular prognathism, no gingival display on smiling and wide buccal corridors (Fig 1).

Dental examination revealed a very narrow maxillary arch and an expanded mandibular arch with vertically positioned posterior teeth, bilateral posterior crossbite, non-coinciding midlines (1.5-mm maxillary deviation to the right and 2-mm mandibular deviation to the left), maxillary (2 mm) and mandibular (4 mm) crowding, asymmetric maxillary and mandibular canines and molars, Class III positioning of canines on both sides, reduced overjet and overbite, and retroclined mandibular incisors (Fig 1).

Figure 1 - Initial facial and intraoral photographs.

Radiographs showed endodontic treatment of teeth #26 and #46, discrete generalized horizontal alveolar bone loss, generalized gingival recession, missing teeth #16, #28 and #38, and tooth migrations in the right maxillary side (Fig 2).

Functional assessment revealed a slight deviation between CR and MIP, and inadequate functional guidances. Respiratory pattern was mixed (mouth and nose breathing) and associated with nocturnal snoring. Tongue posture was low.

Skeletal analysis revealed skeletal Class III pattern (ANB = 0°) and maxillary retrusion (SNA = 80°, SNB = 80°, Wits = -2.5 mm), severe transverse maxillary deficiency, increased mandibular plane and a vertical pattern (SN.GoGn = 36°, FMA = 28°, Y-axis = 61°) (Fig 3 and Table 1).

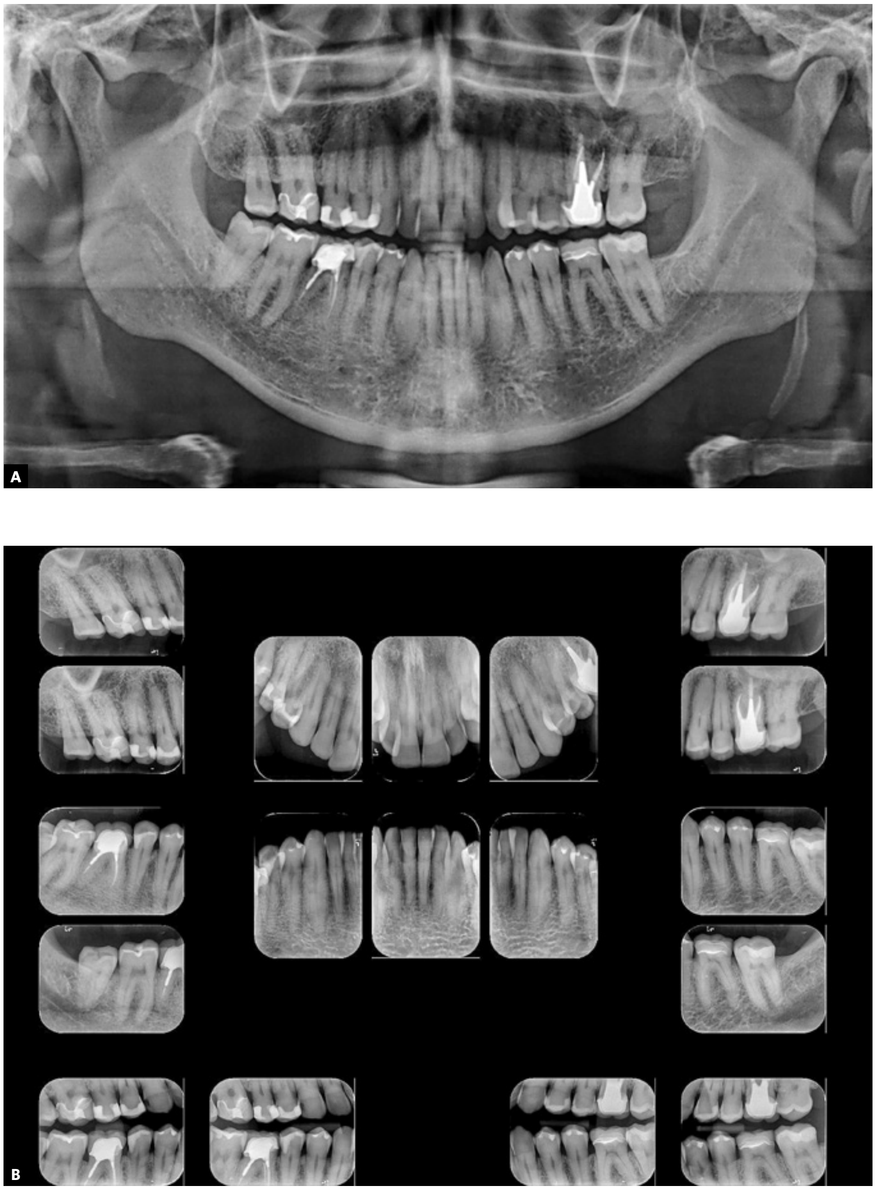

Figure 2 - Initial panoramic (A) and periapical (B) radiographs.

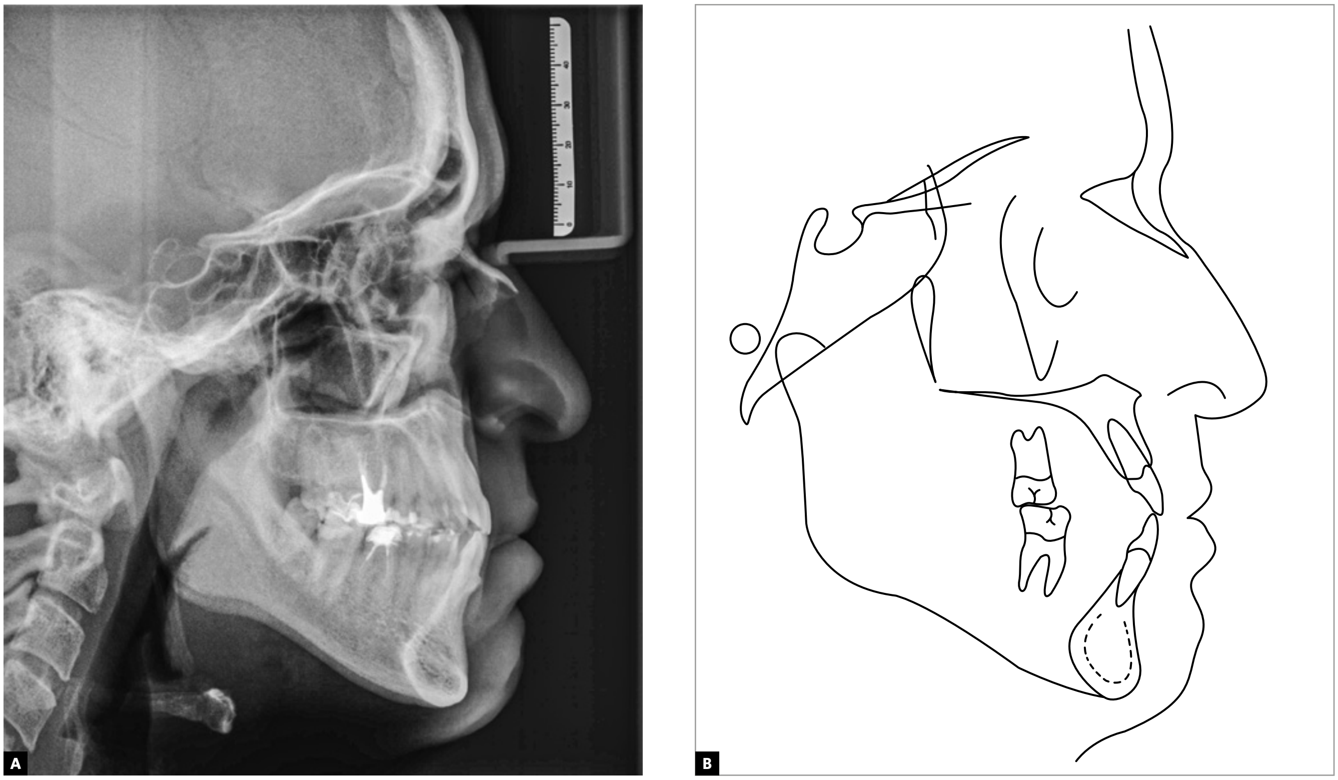

Figure 3 - Initial cephalometric profile radiograph (**A**) and cephalometric tracing (**B**).

Treatment planning and orthodontic mechanics used

As the patient ruled out two-stage surgery and extractions from the beginning, treatment plan consisted of orthodontic camouflage combined with mini-implant anchorage in the mandibular arch for sagittal and vertical correction, and previous SARME to correct the transverse discrepancy.

Treatment objectives were: correct PCB; preserve facial characteristics, to avoid an LAFH increase and favour passive lip seal; improve smile arc, extrude and increase exposure of maxillary incisors, and increase overbite; move maxillary teeth mesially; move mandibular teeth distally and tip them lingually, to gain adequate overjet and sagittal correction.

Treatment started with the placement of a Hyrax expander and SARME surgery. Activation protocol was ¼ of a turn once a day for the first week, and then ¼ of a turn twice a day. However, the gingiva between teeth #11 and #21 showed signs of changes, an indication of gingival recession. At that moment, the expander was partially deactivated and the patient was asked to discontinue activations. Five days later, the patient was told to resume activations at ¼ of a turn once a day for two days, and to discontinue activation at the next day, for 10 days. This protocol was kept for 27 more days, with a favorable response of gingiva, without any recession. After PCB overcorrection, screw opening of 8.25 mm and achievement of a 7-mm interincisal diastema (Fig 4), the patient was referred to a prosthesis specialist for the restoration of central incisors, as he wished to have the diastema corrected. A 3-mm diastema was preserved to start the correction of the maxillary midline and maxillary canine asymmetry. One month after SARME, still during activation, a fixed appliance was bonded to maxillary incisors to stabilize tooth #21. It was anchored to the left side of the expander using a tie-together to ensure that only tooth #11 moved mesially. A full man-

Figure 4 - Intermediate intraoral photographs (after SARME).

dibular fixed appliance was placed (MBT prescription, 0.022x0.028-in slot), and leveling and alignment was performed using 0.014-in, 0.016-in and 0.018-in NiTi and 0.020-in stainless steel archwires.

A mini-implant was placed between teeth #44 and #45, to move teeth #47 and #46 distally using a sliding-jig, and then replaced with another in the mesial aspect of tooth #46, to move the teeth that were anterior to #46 distally, until a canine Class I occlusion.

After four months of stabilization, the expander was removed, and full fixed appliance was placed in the maxillary arch. After that, leveling and alignment was performed using 0.016-in and 0.017x0.025-in NiTi and 0.020-in and 0.019x0.026-in stainless steel archwires and elastics (more marked Class III in right side), associated with anchorage loss in the right side. In the finishing stage, a 0.019x0.025-in stainless steel rectangular archwire with additional bends was placed. The prosthesis specialist adjusted occlusion using selective grinding, which favored occlusal fit and vertical reduction, achieving adequate overbite. Treatment was concluded in 34 months and 28 orthodontic controls. A maxillary removable wraparound retainer was manufactured using a 0.036-in stainless steel wire. The appliance had to be used 24 hours a day for six months, for one more year during the night, and on alternate nights for six months after that. A fixed retainer manufactured with 0.028-in stainless steel wire was bonded to teeth #33 and #43. The patient was then referred to the prosthesis specialist for final restorations.

Results

Treatment objectives were achieved. The smile arc improved and the buccal corridors were reduced, as the distances between maxillary canines increased from 29 mm to 34 mm, and between maxillary molars, from 45 mm to 51 mm. Despite the fact that orthodontic camouflage was limited, final occlusion was highly satisfactory, with Class I molar and canine relationships, adequate overjet and overbite, and proper functional guidance free of interferences, which were a result of occlusal adjustment (Fig 5). The patient's facial profile remained concave, but the upper lip gained better support because of the type of orthodontic camouflage conducted: maxillary incisor protrusion and mandibular incisor retrusion. Sagittal and vertical

Figure 5 - Final facial and intraoral photographs before restorative procedures.

skeletal characteristics were preserved (Figs 6 and 7; Table 1). The patient reported a significant improvement in breathing immediately after SARME and chose not to undergo a speech and hearing evaluation for tongue posture, because he was satisfied with treatment results.

Total superimposition of cephalometric tracings showed few changes. Partial superimposition of the maxilla showed distal movement and slight extrusion of molars, as well as extrusion and increased tipping of incisors. Partial superimposition of the mandible revealed very little movement of molars, as well as extrusion and retroclination of incisors (Fig 8).

DISCUSSION

Maxillary expansion is a safe and efficient alternative for the treatment of maxillary deficiency[24]. In children and adolescents, the MPS is open or has very little interdigitation, and, therefore, orthopedic expansion has a good prognosis.[13] However, in adults, resistance due to MPS fusion[32,33] and to the structures adjacent to the maxilla, particularly the zygomatic buttress[5,19] and pterygopalatine structures,[19] may limit the skeletal effects of RME. For these patients, SARME is a treatment option, as it eliminates resistance in some areas of the maxilla.[2,5,6]

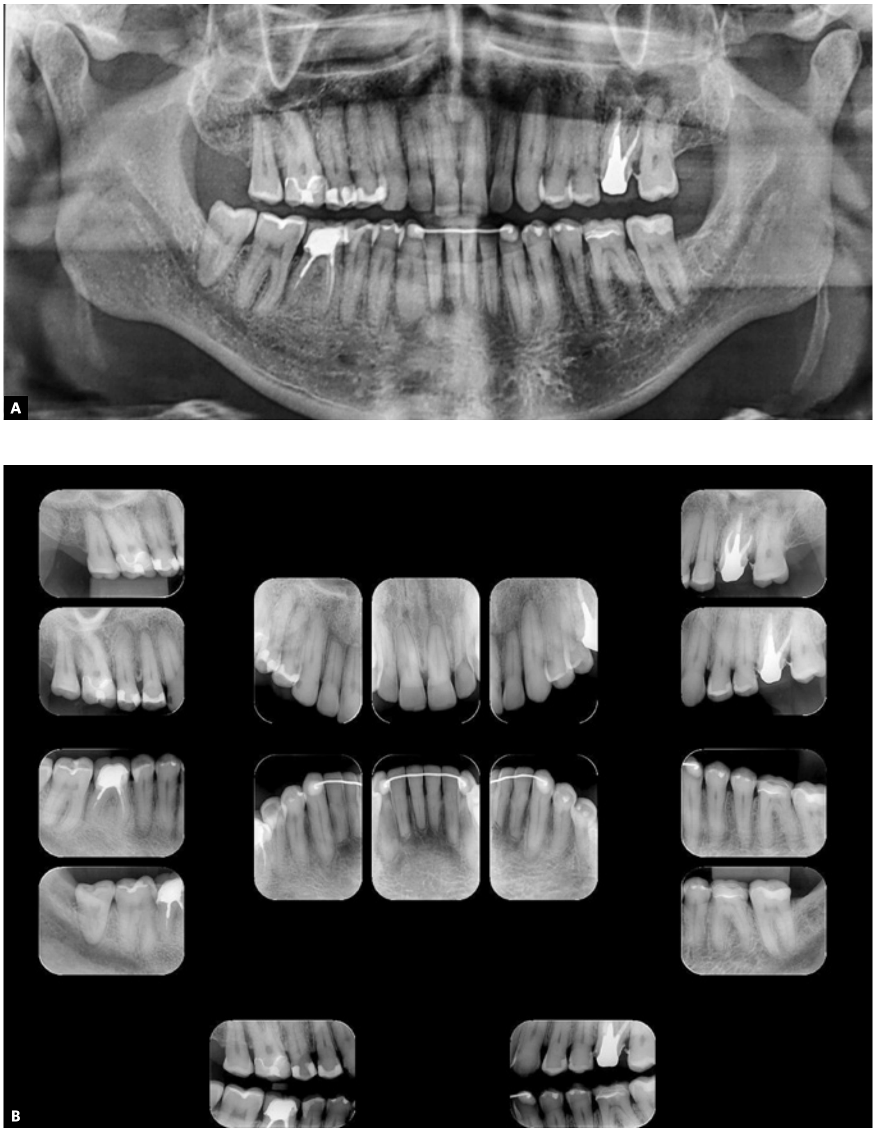

Figure 6 - Final panoramic (A) and periapical (B) radiographs.

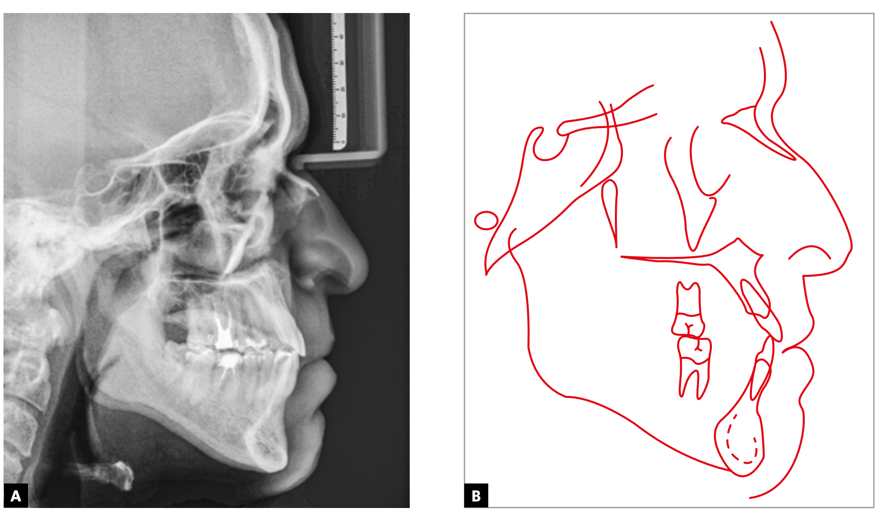

Figure 7 - Final cephalometric profile radiograph (A) and cephalometric tracing (B).

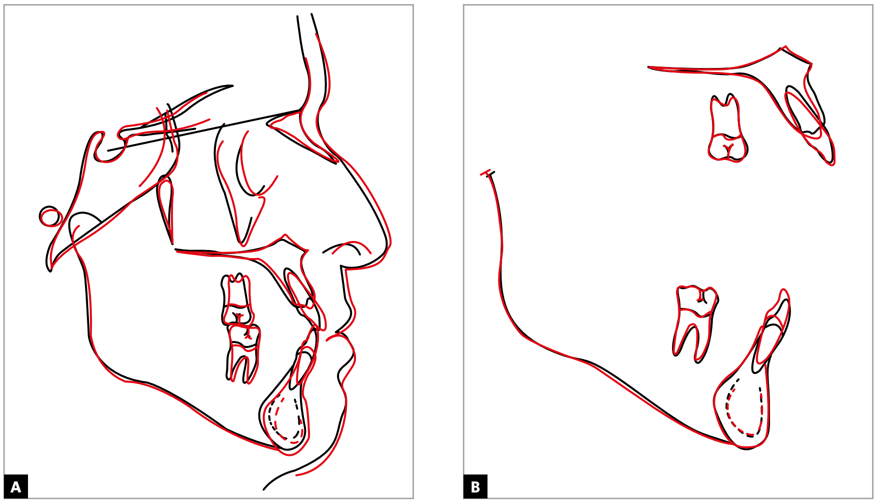

Figure 8 - Total (A) and partial (B) superimpositions of initial (black) and final (red) cephalometric tracings.

Table 1 - Initial (A) and final (B) cephalometric values

	Measurements		Normal	A	B	Dif. A/B
Skeletal pattern	SNA	(Steiner)	82°	80°	80°	0
	SNB	(Steiner)	80°	80°	80°	0
	ANB	(Steiner)	2°	0	0	0
	Wits	(Jacobson)	♀ 0 ± 2mm ♂ 1 ± 2mm	-2.5mm	-2.5mm	0
	Angle of convexity	(Downs)	0°	-1°	-2°	-1
	Y-axis	(Downs)	59°	61°	61°	0
	Facial angle	(Downs)	87°	88°	88°	0
	SN.GoGn	(Steiner)	32°	36°	36°	0
	FMA	(Tweed)	25°	28°	28°	0
Dental pattern	IMPA	(Tweed)	90°	86°	82°	-4
	$\underline{1}$.NA (degrees)	(Steiner)	22°	27°	31°	4
	$\underline{1}$-NA (mm)	(Steiner)	4mm	7mm	9mm	2
	$\overline{1}$.NB (degrees)	(Steiner)	25°	20°	15°	-5
	$\overline{1}$-NB (mm)	(Steiner)	4mm	6mm	6mm	0
	$\frac{1}{1}$ - Interincisal angle	(Downs)	130°	134°	135°	1
	$\frac{1}{1}$ - Apo	(Steiner)	1mm	4mm	4.5mm	0.5
Profile	Upper lip — S-line	(Steiner)	0	-2mm	-2mm	0
	Lower lip — S-line	(Steiner)	0	1mm	1mm	0

In the clinical case described here, severe maxillary deficiency associated with bilateral posterior and anterior crossbite, in addition to negative discrepancy in both arches, led to the choice of SARME as the first treatment option. The type of expander used for SARME may be tooth-borne, tissue-tooth-borne or bone-borne. Some authors[5,14-19] recommend expanders in combination with temporary devices for absolute anchorage, to reduce the effects of the inclination of posterior teeth and of the two maxillary halves, as well as to achieve bone separation by lateral translation. However, according to Sevillano,[19] randomized controlled trials have not found differences in tooth movement during expansion with or without skeletal anchorage. In the case presented here, a Hyrax expander was selected because it provides satisfactory results in SARME, good hygiene control, is easy to manufacture and has a low cost. The conventional fixed appliance was placed in the mandibular arch immediately after maxillary expansion, which ensured the buccolingual decompensation of mandibular teeth, as well as the dentoalveolar expansion of the mandibular arch. This was especially true in the region of canines, where the distance between teeth went from 23 mm to 25 mm, and of mandibular second molars, especially tooth #37, for which initial lingual tipping was increased.

Expander activation started four days after surgery, although some studies recommend immediate activation.[2,7,9-12] Initial activation protocol had to be adapted to prevent gingival recession or dehiscence in the region, as the gingiva between maxillary central incisors underwent changes. According to some authors,[6,26] this might have been the result of an asymmetrical fracture of the MPS in the area between incisors, but there was no radiographic control to confirm it. Surgical planning for this case did not include any recommendation of previous divergent orthodontic movement of the roots of maxillary central incisors to avoid changes in interincisal papilla, as suggested by França and Moscardini.[6] Therefore, activations were conducted at longer intervals to ensure the preservation of the health of interincisal gingiva, as suggested by Oliveira et al.[26]

No consensus has been reached about retention time after expander stabilization, whether it should be three[9,10,12] or six[7,11,27] months. However, because of the patient's complaints about having to keep the appliance after four months, radiographs were obtained to evaluate new bone formation in the MPS and remove the expander. A removable appliance was then placed, both as a precaution and to ensure SARME stability. It should be used continuously for two months, and every night for one month after that, together with the conventional orthodontic appliance placed in the maxillary arch.

Before SARME, the patient reported that his nasal breathing was not satisfactory. No specific evaluation of this function was conducted, but the patient identified a significant improvement in nasal breathing and in sleep quality immediately after SARME, which corroborates other evidence[20-24] about the benefits of SARME for nasal breathing.

According to McNamara,[24] maxillary deficiency syndrome is found in about half of the patients with Class III malocclusion and skeletal maxillary retrusion, which is associated with posterior and anterior crossbite and maxillary crowding. The patient in the case presented here had maxillary deficiency, skeletal Class III malocclusion due to maxillary retrusion, according to the cephalometric analysis (Fig 3 and Table 1), posterior and anterior crossbite and severe mandibular crowding. Although ideal treatment would involve a second surgical stage to correct Class III sagittal skeletal discrepancy, as well as an extraction in the right hemimandible because of mandibular crowding and asymmetry between canines, these options were ruled out by the patient. Therefore, treatment consisted of orthodontic camouflage for sagittal correction, together with the use of intermaxillary elastics and distal movement of the right mandibular teeth using a mini-implant and a sliding jig,[36] achieving satisfactory results. Tooth alignment, a better smile arc shape and the narrowing of the buccal corridors were fundamental to improving smile aesthetics.

RME combined with the use of mini-implant, a procedure known as MARPE, is more conservative and has lower costs and risks than SARME, and, because of that, has gained attention in the literature.[15-19] However, it is primarily indicated for young adults in their 20s to 30s, although no age limits are found in the literature. Bortolotti et al.[8] recommend nonsurgical RME for adult patients, because the skeletal expansion achieved with SARME is minimal and there is the risk of the morbidities inherent to surgery. However, in the case presented here, the more advanced age of the patient (53 year-old) and the severity of malocclusion favored the indication of SARME. No other treatment was considered at the time because of the chances of failure in case conventional RME or MARPE were used, as the sagittal compensation initially planned would not be achieved, and periodontal risk would be greater.

Treatment results were in agreement with changes already described in the literature: increase in maxillary alveolar width[5] and maxillary intercanine and intermolar distances;[3,5,11,22] posterior crossbite correction; reduction of palate height; significant increase in palate width;[3] and increased maxillary arch perimeter[11] and length.[11,22] Skeletal changes achieved with SARME were stable, despite some relapse in dental expansion due to the lingual movement of the maxillary first molars, as also reported by Chamberland and Proffit.[27]

CONCLUSION

According to the literature and the clinical case presented here, maxillary deficiency and posterior crossbite in an adult patient at an advanced stage of skeletal maturation may be efficiently corrected using SARME, with stable and satisfactory functional and aesthetic results of the skeletal, dental and smile changes.

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Conception or design of the study: LL. Data acquisition, analysis or interpretation: LL. Writing the article: LL. Critical revision of the article: LL, CEF. Final approval of the article: LL, CEF.

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Adult mesenchymal stem cells and their possibilities for Dentistry: what to expect?

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Introduction: Stem cells obtained from the pulp of human deciduous teeth are highly proliferative and plastic multipotent cells, which makes them a relevant model of stem cells, applied in several biomedical areas, with different purposes.

Objective: Based on a brief review of the literature, the present work intends to present from conceptual aspects about stem cells, classifications, potential (*in vitro* and *in vivo*) applications in dental practice, cell culture, cryopreservation and its importance, ethical and regulatory aspects, as well as the role of the dental surgeon as the endorser responsible for the entire clinical stage that involves the process of collecting stem cells obtained from dental pulps for cryopreservation, with a view to using them under appropriate conditions, in accordance with scientifically proven and justified good laboratory and clinical practices.

Keywords: Mesenchymal stem cells. Regenerative dentistry. Cell therapy. Tissue bioengineering. Cryopreservation.

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INTRODUCTION

The search for longevity associated with good quality of life has accompanied the history of humanity since the beginning of time. Over the past 50 years, we have increased our life expectancy, worldwide, by approximately 30 years.[1] Much of this is due to small changes in habits and major scientific and clinical advances that have enabled the implementation of increasingly effective prevention, control and treatment measures for so-called infectious diseases. In those places where such measures have been successfully established, considering the socioeconomic and cultural aspects involved, these diseases today account for about 5% of the indices mortality.[2] However, there is still much to be done, and today so-called degenerative diseases represent a major challenge to be overcome so that we can move forward with the purpose of living longer and living well.

There is no doubt about the important role played by Dentistry along this journey. After all, many of the pathologies that affect the stomatognathic system have decisive systemic consequences for the longevity-quality of life binomial to be enforced.

From the twentieth century, Cell Biology and Genetics began to contribute as diagnostic tools and therapies aimed at treating many of the ills that afflict humanity. In the 50s, it was carried out, by Edward Donnall Thomas, the first bone marrow transplant. In 1961, James Till and Ernest McCulloch pointed to the existence of hematopoietic stem cells in the bone marrow of mice, opening a perspective for understanding the mechanisms involved in these transplants.[3] Between the 70s and 80s, Professor Alexander Friedenstein's team, studying mesenchymal stem cells, demonstrated the capacity for self-renewal and differentiation of these cells, attracting attention from the scientific community to the need to promote research aimed at the use, in a targeted and predictable way, of this biological material, in relation to embryonic stem cells already known previously (Fig 1).

Adult mesenchymal stem cells present themselves as an important instrument within the fields of Regenerative Medicine and Dentistry, as they are cells that, despite being nonspecific, have a great capacity for multiplication, differentiation into specialized cells and constituents of specialized tissues and with immunomodulatory competence. There are reports of a large number of places from which adult mesenchymal stem cells can be isolated, such as: bone marrow,[4] adipose tissue,[5] musculoskeletal tissue[6], labial orbicularis muscle[7], dental pulp[8], dermis[9] and pulp of primary teeth.[10]

STEM CELLS AND THEIR POSSIBILITIES IN REGENERATIVE DENTISTRY AND MEDICINE

1. Stratification of patients: use of stem cells to recreate a specific disease in the laboratory (Alzheimer's, Autism, Parkinson, etc.) and, thus, allow a more detailed investigation of the disease, so that new treatments can be developed (Fig 2).

2. Drug development and testing: use of stem cells to generate tissues or organs of interest for the development and testing of new drugs, allowing for a local and systemic evaluation without the need for tests on animals and humans (Fig 3).

3. Generation of functional organs in the laboratory: by directing the differentiation of stem cells associated with a specific framework (previously decellularized organ), generating functional and immunologically compatible organs[14-16] (Fig 4).

4. Cell therapy: by transplanting or injecting live stem cells, differentiated or not, into a patient, in order to replace or regenerate damaged cells or tissues (Fig 5).

MESENCHYMAL STEM CELLS OF DECIDUOUS PULPS: WHAT THE DENTAL SURGEON NEEDS TO KNOW

Adult stem cells are classified, according to their origin, into hematopoietic and mesenchymal (Fig 6). Stem cells of hematopoietic origin are able to differentiate into specialized cells of white and red blood lines, while mesenchymal cells are able to differentiate into specialized cells that form hard tissues and organs, such as bones, cartilages, muscles, nerves, among others (Fig 6).

The stem cells present in the dental pulps are classified as mesenchymal, due to their ectomesenchymal embryonic origin, which gives them the ability to differentiate into a large number of specialized cells in the human body, such as bone, cartilage, muscle, neuronal cells, cardiac, pancreatic, among others. The youthfulness of these stem cells present in the pulps of deciduous teeth that will be lost and replaced

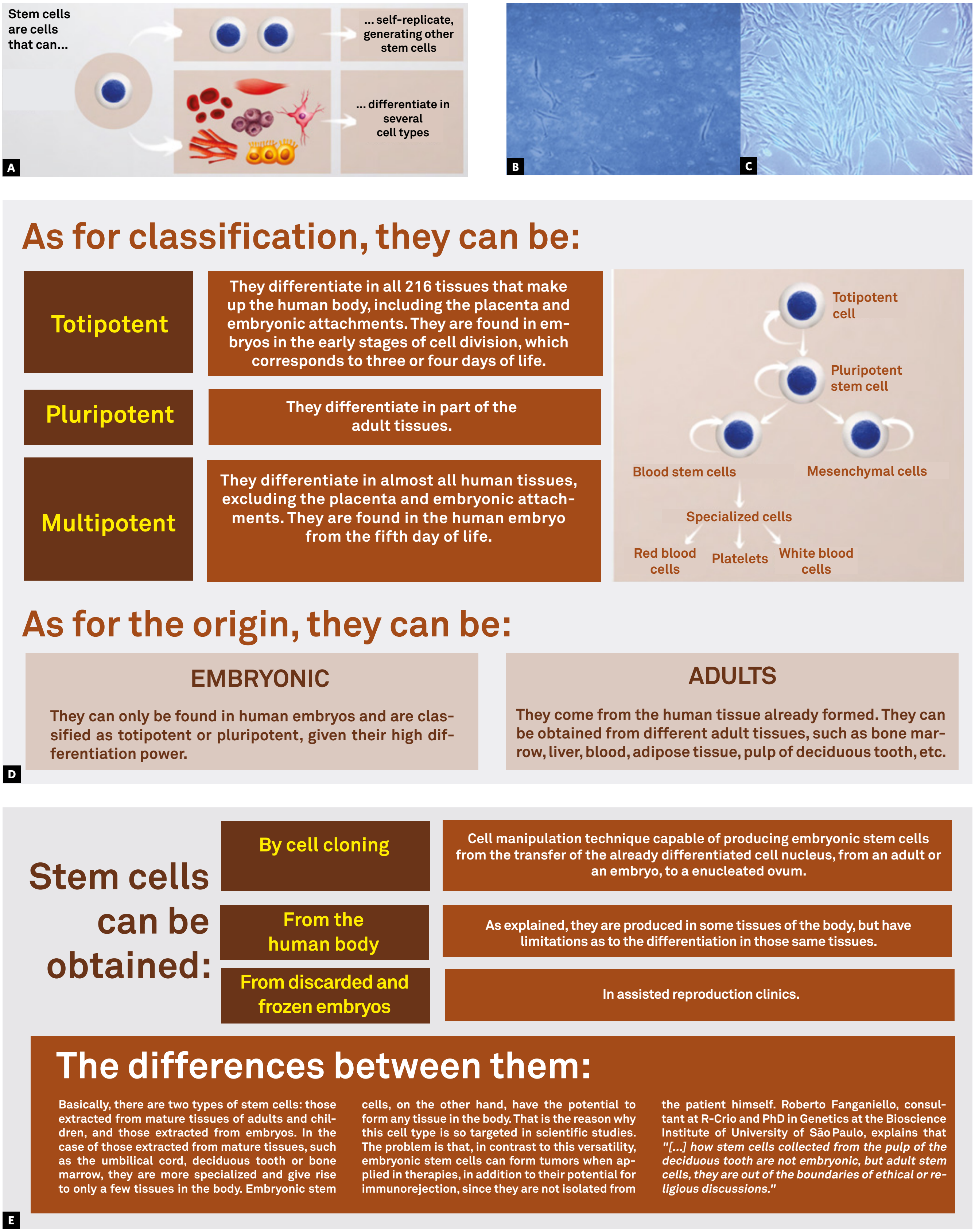

Figure 1 - A) Stem cells are called nonspecific, and therefore have a great capacity for multiplication and differentiation. B) Image obtained by optical microscopy (10X), in which the presence of mesenchymal stem cells isolated from a deciduous dental pulp (4 days of culture) can be observed. C) Image obtained by optical microscopy (10X), in which the presence of isolated and expanded mesenchymal stem cells can be observed in the laboratory (12 days of culture, in confluence). D) Classification of stem cells according to their potential for differentiation and origin. E) Ways to obtain stem cells and differences between adult and embryonic stem cells.

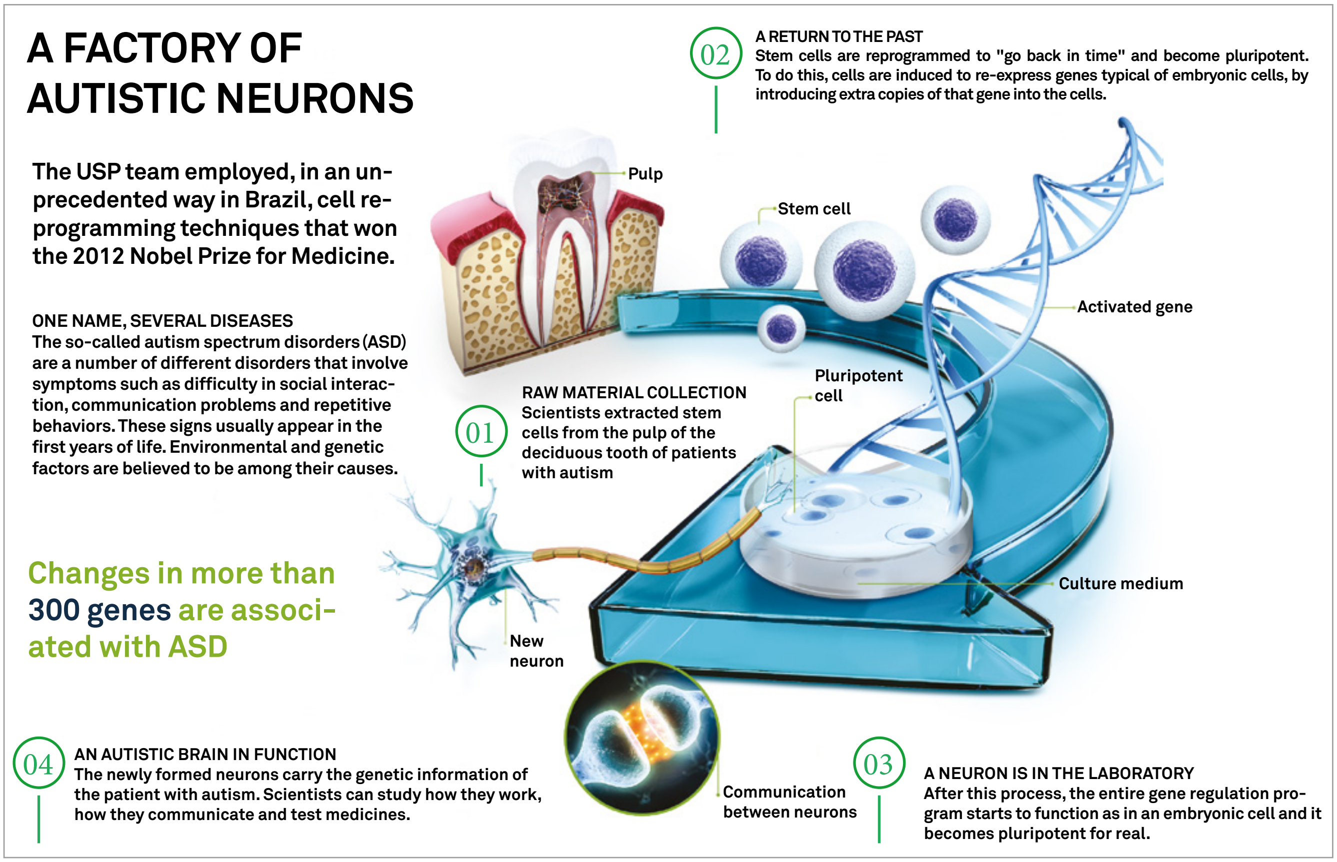

Figure 2 - Infogram based on the article by Griesi-Oliveira et al.[12]

by permanent dentition, approximately between 6 and 12 years of age, added to their expressive capacity for multiplication and plasticity in the laboratory, in addition to the high immunomodulatory potential, make this model stand out from other existing sources of mesenchymal stem cells (Fig 7).

The performance of the dental surgeon is essential as the homologator of this applied science, as responsible for monitoring the child and choosing the best tooth for performing the collection. The promotion and maintenance of oral health since childhood is a decisive step towards the viability of the pulp stem cell cryopreservation process. The dental unit chosen may be deciduous in the process of exfoliation, with 1/3 of the root volume remaining (the presence of the underlying permanent must be confirmed, with 2/3 of rhizogenesis completed) or a third molar in the process of rhizogenesis, so that the entire process of isolation, multiplication and validation of the stem cells to be cryopreserved is favored, in suitable conditions, for autologous use in advanced therapies, when and if necessary (Fig 8).

Stem cells from dental pulps express osteogenic markers and respond to many growth factors for osteo-odontogenic differentiation,[17-21] and also multiply very easily and with quality in the laboratory.

There are many applications and potentials for the use of these stem cells, which go far beyond the boundaries of Dentistry itself. For Dentistry, specifically, the osteogenic potential and the ability to regenerate complex tissues —such as the pulp, periodontal ligament and the tooth itself— give the dentist new and powerful tools, which need to be presented to society in a responsible manner.

Cell Processing Centers fulfill the role of promoting the proper treatment and storage of these stem cells, following the internationally established protocols of good practice, so that they can be used when and if necessary, in autologous or allogeneic form, in line with current regulations established by the competent regulatory agents.

In Brazil, regulatory advances regarding the so-called advanced therapies, that make use of stem cells or factors obtained from these, have been happening more and more rapidly and consistently. The resolutions published

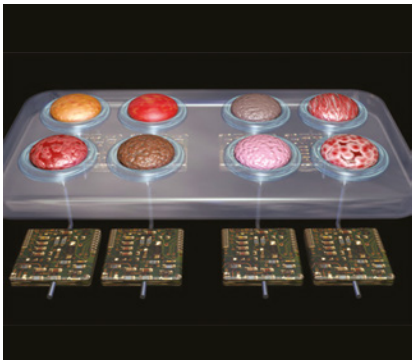

Figure 3 - Microfluidics: technology that allows creating organs on chips. Source: Bombaldi,[13] 2019.

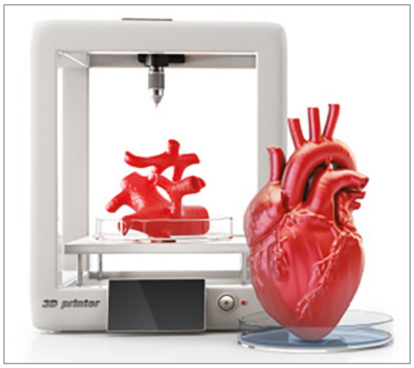

Figure 4 - Generation of organs in the laboratory.

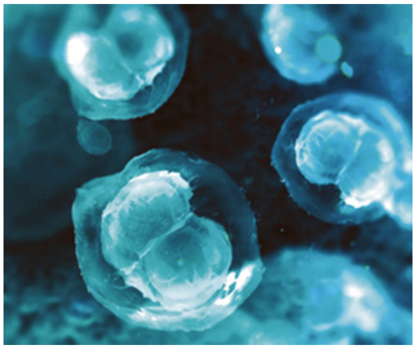

Figure 5 - Stem cells in cell therapy.

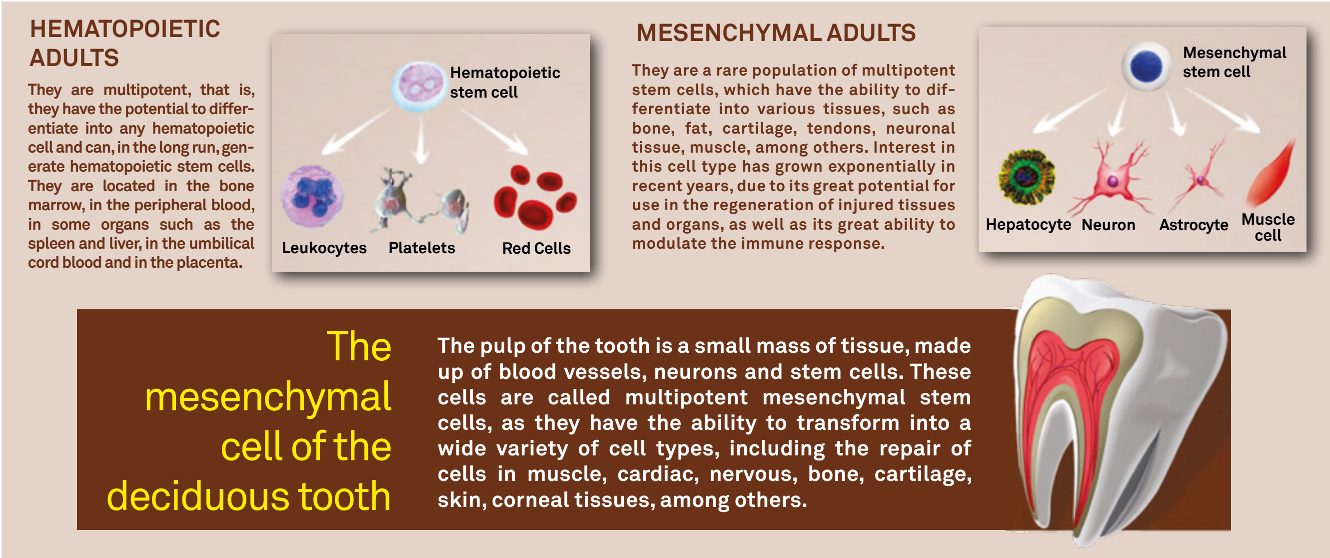

Figure 6 - Comparative illustration between adult hematopoietic and mesenchymal stem cells.

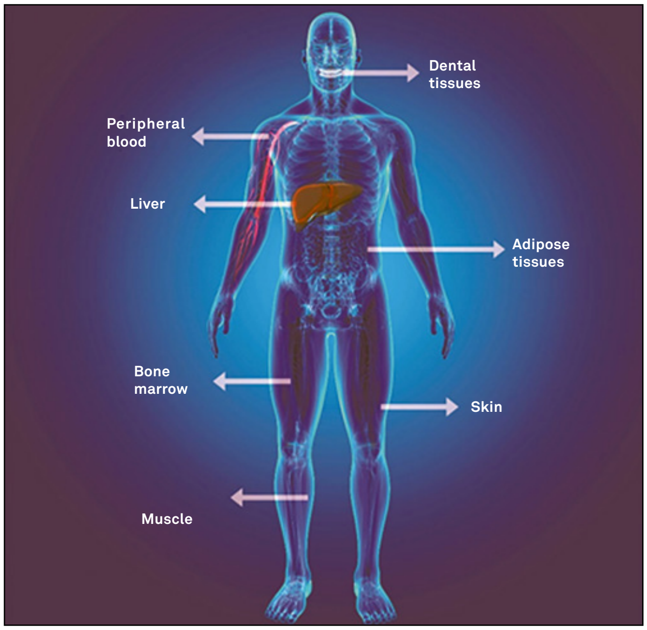

Figure 7 - Sources of mesenchymal stem cells.

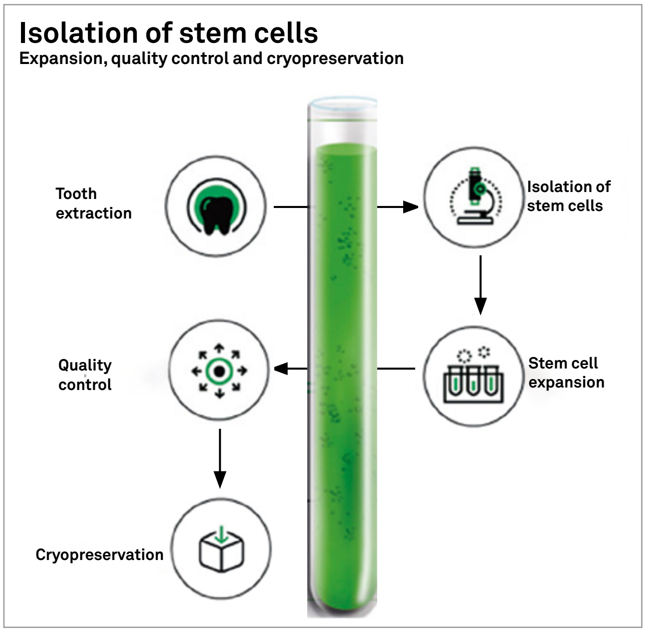

Figure 8 - Infographic with sequence of events for cell cryopreservation.

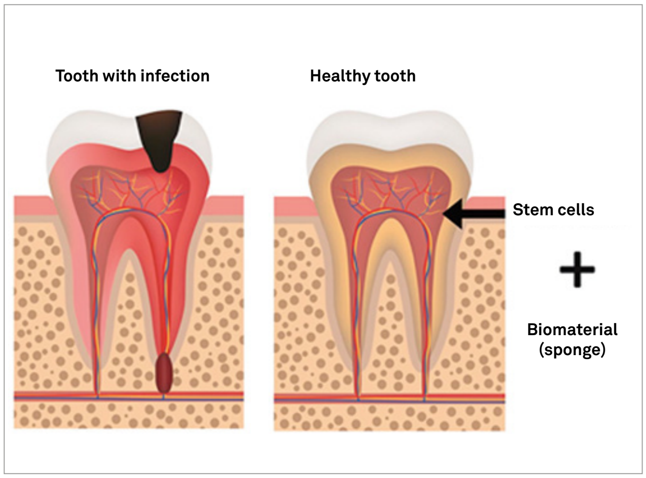

Figure 9 - Illustration of pulp regeneration.

by ANVISA (214/2018[22] - Good Practices in Human Cells for Therapeutic Use and Clinical Research, and 260/2018[23] - Rules for Conducting Clinical Trials with Advanced Investigational Therapy Product in Brazil), are an important demonstration of the environment favorable to the solid development of effectively innovative and transforming therapeutic protocols.

Cell Therapy brings the proposal to effectively and integrally regenerate tissues or organs morphologically, structurally and functionally damaged. Adult stem cells are presented as an important instrument, capable of leading and acting in this process in a decisive way. Countless basic and applied researches have been carried out all over the world, in order to prove the safety, efficacy, reproducibility, advantages and accessibility for the use of adult stem cells in Regenerative Medicine and Dentistry.[24]

POSSIBLE CLINICAL APPLICATIONS OF MESENCHYMAL STEM CELLS IN DENTISTRY

1. Regeneration of pulp tissue

In Brazil, in 2015, a group from the Faculty of Dentistry of the University of São Paulo (USP) presented, in a preclinical study in rats, a complete regeneration of the pulp tissue after 28 days of the pulpectomy and inoculation of autologous stem cells at the site.[34] In 2017, Nakashima et al.[25] carried out the first clinical study with the purpose of evaluating the regenerative potential of pulp stem cells in pulp tissues affected by pulpitis, through autologous transplants. In this study, five patients diagnosed with irreversible pulpitis were submitted to endodontic treatment and then treated with autologous stem cells, with follow-up for 24 weeks. Pulp stem cells were associated with specific SDF1 factors (Factor 1 derived from stromal cells) in a collagen framework, since, according to the authors, the Regenerative Medicine triad — composed of progenitor cells, growth / migration factors and a framework — is essential for the "ideal" regenerative process to happen. After four weeks, they were able to verify a robust regenerative response, through electric pulp testing (EPT). At 24 weeks, through magnetic resonance imaging and computed tomography, they were able to observe the presence of regenerated pulp tissue and formation of functional dentin (Fig 9).

2. Expanding the limits of orthodontic movement

There are several factors that limit the extent of orthodontic movement,[26] among which we can highlight the bone envelope, which is influenced by the pressure exerted by the adjacent soft tissues, neuromuscular forces and levels of periodontal insertion. Orthodontic movement is achieved by remodeling of the adjacent periodontal ligament in response to the load imposed from its constriction in the region influenced by the action of compressive orthodontic loads.[27] Osteoclasts from hematopoietic stem cells[28] are recruited to act directly in the bone remodeling process, accelerating the orthodontic movement.

The influence on orthodontic movement speed in relation to the expression of type-1 collagen by stem cells from the adjacent periodontal ligament was demonstrated, based on a study carried out in rats.[29] The authors observed the suppression of local type-1 collagen, by stem cells of the periodontal ligament, during the application of orthodontic load, and an increase in local expression after the removal of this load.

The use of stem cells can then represent an important window of opportunity for the bone remodeling process determined by the applied orthodontic forces to happen more quickly and predictably[27,29] (Fig 10).

The tissue bioengineering strategy aimed at regenerating and/or increasing the bone ridge using mesenchymal stem cells from deciduous pulps associated with a biomaterial (framework) with osseoconductive, osseoinductive and bioactive properties is an excellent option to be considered in conditions ranging from the adequacy of the bone rim for orthodontics, to more extensive procedures aimed at orthopedics,

Figure 10 - Expansion of orthodontic movement limits.

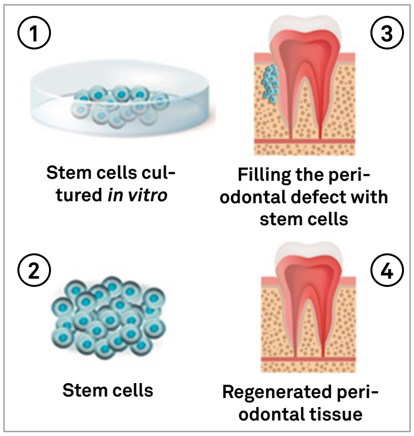

Figure 11 - Mesenchymal stem cells for periodontal regeneration.

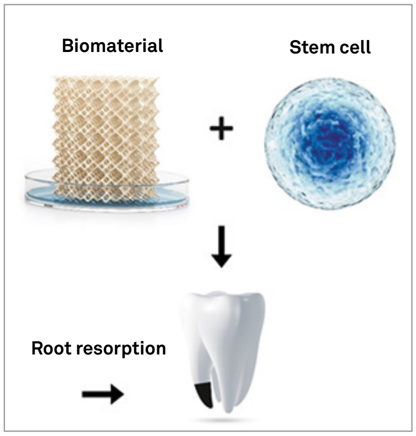

Figure 12 - Mesenchymal stem cells undergoing root regeneration (external resorption).

such as dentofacial anomalies (cleft lip and palate), temporomandibular disorders, osteogenic distractions and maxillary expansions.

3. Periodontal regeneration

The periodontal phenotype must be considered with great attention in orthodontic planning, as cases of fenestration or gingival recession as a result of inappropriate orthodontic movement are not uncommon. However, once the framework is established, Guided Tissue Regeneration (GTR) techniques are a way to minimize the damage caused by the defect (Fig 11). Several authors have suggested that the path through GTR may have its results greatly improved if stem cells are associated with the process. Stem cells from the periodontal ligament have been especially considered in animal models[30,31] and have been shown to be able to form specific periodontal structures when implanted in ectopic sites.[32]

4. External root resorption

This is a complication that often results from orthodontic treatments, and leads to loss of cementum and root dentin. The cementogenic potential of stem cells from the periodontal ligament and pericoronary follicle was investigated, considering that the cells that form the cementum are derived from these stem cells.[33] The authors observed that stem cells from the periodontal ligament isolated by enzymatic digestion had special characteristics for cementogenesis. They were able to form, *in vivo*, a tissue similar to cell cementum, containing cells positive for osteocalcin. The other samples, on the other hand, formed materials similar to an acellular cementum. Considering that the defect in the root cementum must be regenerated from the deposition of new cell cementum, the use of stem cells from the periodontal ligament isolated by enzymatic digestion may constitute a path to be followed in therapeutic attempts for regeneration in cases of external resorption root (Fig 12).

FINAL CONSIDERATIONS

The use of adult mesenchymal stem cells has been consolidated in the scientific and clinical communities, as an important tool for Regenerative Medicine and Dentistry. Therefore, it is necessary that applied research be strongly promoted, so that we have, in a short period of time, therapeutic possibilities increasingly efficient, safe, predictable and accessible to society without distinction. Clinicians face the challenge of disseminating information based on scientific evidence to the whole of society, giving the real dimension to this very important science. Dental surgeons are the only professionals qualified to choose and remove dental units for the purpose of cryopreservation of dental pulp stem cells. This exclusivity places Dentistry in a prominent position among the scientific community. Cell Processing Centers must continue to fulfill their important role of caring for and providing stem cells in conditions suitable for use in properly regulated research and advanced therapies. Finally, the competent regulatory entities must establish guidelines for good practices applied to laboratories, hospitals, clinics, therapy centers and professionals, while the Dentistry and Medicine Councils must coordinate, through the constitution of competent technical committees, the approval of the various possibilities of cell therapies that are described, proven and registered, in accordance with the international recommendations proposed by the main organized societies, such as the International Society for Cell and Gene Therapy (ISCT) and the International Society for Stem Cell Research (ISSCR).

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GUIDELINES FOR SUBMISSION OF MANUSCRIPTS

— All articles must be written in English.

— Manuscripts must be submitted via http://mc04.manuscriptcentral.com/dpjo-scielo.

— Articles must be organized as described below and according to the NCBI Style Guide available at: http://www.ncbi.nlm.nih.gov/books/NBK988/.

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— The number of authors is unlimited. However, the authors should inform the contribution of each one, using two minimum criteria of authorship: a) Actively participate in the discussion of the results; b) Review and approval of the final version of the work. Also, at the time of submission, each author's ORCID ID (Open Researcher and Contributor ID, http://orcid.org) must be informed in a specific field in the user profile on the submission platform.

2. Abstract

— Abstracts should be structured and comprise 250 words or less.
— Structured abstracts must contain the following sections: INTRODUCTION, outlining the objectives of the study; METHODS, describing how the study was conducted; RESULTS, describing the primary results; and CONCLUSIONS, reporting the authors' conclusions based on the results, as well as the clinical implications.
— Abstracts must be accompanied by 3 to 5 keywords, or descriptors, which must comply with MeSH controlled vocabulary thesaurus (www.nlm.nih.gov/mesh).

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— The text must not include information about the authors (e.g., authors' full names, academic degrees, institutional affiliations and administrative positions). They should be included in specific fields of the article submission website, only. Thus, this information will not be available during review process.
— Text must be organized in the following sections: Introduction, Material and Methods, Results, Discussion, Conclusions, Citations and Figure captions.
— Texts must contain no more than 4,000 words, including captions, abstract and citations.
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— Also insert Figures captions in the text document so as to guide the article layout.

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— Digital images must be in JPG or TIF formats, CMYK or grayscale, at least 7 cm wide and with 300 dpi resolution.
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5. Data charts and cephalometric tracings

— Files containing the original version of charts and tracings must be submitted.
— It is not recommended that such charts and tracings be submitted solely in bitmap image format (noneditable).
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— Tables must be self-explanatory and should supplement, not duplicate the text.
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— Articles must, if applicable, refer to opinions of the Ethics Committees, without, however, specifying the name of the university, college, school or department (thus, this information will not be available to reviewers).

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— DPJO supports initiatives aimed at improving the report of biomedical research. Thus, authors are requested to make use of available reporting guidelines and checklists for biological and biomedical research, whenever applicable.
— **Before submitting your systematic review, please make to sure to attend the following requirements:**
— Use the PRISMA statement (http://www.prisma-statement.org) as guideline to report the systematic review.
— The PRISMA checklist (http://www.prisma-statement.org/PRISMAStatement/Checklist) should be completed and uploaded with the submission.
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— Meta-analysis should only be included if properly justified. They should be part of the systematic review frame.

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All manuscripts must be accompanied by the following statements to be attached during the submission process:

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Authors should disclose any financial competing interests, but also any nonfinancial competing interests that may cause them embarrassment if they were to become public after the publication of the article.
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Research involving human subjects, human material, or human data must have been performed in accordance with the Declaration of Helsinki and must have been approved by an appropriate Ethics Committee. A statement detailing this, including the name of the Ethics Committee and the reference number, where appropriate, must appear in all manuscripts reporting such research.
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— Informed consent form
For all research involving human subjects, an informed consent form should be obtained from subjects participating in the study (or their parent or guardian in the case of children under 16), and a statement to this effect should appear in the manuscript.

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— Authors should not cite sources that they have not read.
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— Authors should not cite advertisements or advertorial material.
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- GUIDELINES FOR DPJO CASE REPORTS

— Case reports are published on a regular basis in the DPJO. In order to standardize the clinical cases presented the authors should follow the protocol described below unless, for a very particular reason, the items below cannot be followed. The authors should try to be objective in their report, which will be judge by the uniqueness of the case, quality of the records and knowledge contributed to the clinicians.

Abstract

— The abstract should be structured following a one or two sentences description of a brief introduction and aim of the manuscript, treatment objectives, results and conclusion.

Introduction

— 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;

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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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Comprehensive approach to simultaneous molar intrusion and canine retraction in the treatment of Class II anterior open bite using miniscrew anchorage

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DOI: *https://doi.org/10.1590/2177-6709.25.3.30.e1-12.onl*

Introduction: Anterior open bite is one of the most difficult malocclusions to correct in orthodontic treatment. Molar intrusion using miniscrew anchorage has been developed as a new strategy for open bite correction; however, this procedure still has an important concern about prolonged treatment duration in the patient with anteroposterior discrepancy due to the separate step-by-step movement of anterior and posterior teeth.

Objective: This article illustrates a comprehensive orthodontic approach for dentoalveolar open bite correction of an adult patient, by using miniscrew.

Case report: A woman 19 years and 5 months of age had chief complaints of difficulty chewing with the anterior teeth and maxillary incisor protrusion. An open bite of -2.0 mm caused by slight elongation of the maxillary molars was found. The patient was diagnosed with Angle Class II malocclusion with anterior open bite due to the vertical elongation of maxillary molars. After extraction of the maxillary first premolars, concurrent movements of molar intrusion and canine retraction were initiated with the combined use of sectional archwires, elastic chains and miniscrews.

Results: At 4 months after the procedure, positive overbite was achieved subsequent to the intrusion of maxillary molars by 1.5 mm and without undesirable side effects. Class I canine relation was also achieved at the same time. The total active treatment period was 21 months. The resultant occlusion and satisfactory facial profile were maintained after 54 months of retention.

Conclusion: The presented treatment shows the potential to shorten the treatment duration and to contribute to the long-term stability for open bite correction.

Keywords: Open bite. Orthodontic anchorage procedures. Angle Class II. Tooth movement technique.

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INTRODUCTION

Successful correction of anterior open bite is considered one of the most difficult task in orthodontics, and ensuring the long-term stability of the treatment outcome is an important factor to be considered when choosing the method of treatment for patients with anterior open bite.[1,2] Combined surgical-orthodontic treatment is mainly proposed as the common treatment approach for adult patients with severe skeletal maxillomandibular discrepancy.[3,4] Conventional orthodontic treatment methods, such as multiloop edgewise archwire (MEAW)[5] and nickel-titanium wire with intermaxillary elastics,[6] have also been used for patients who are reluctant to undergo surgery for open bite correction. Although the patients treated with these modalities achieved adequate overbite, the changes were mainly caused by the extrusion of the anterior teeth, since molar intrusion is relative to incisors extrusion due to the intermaxillary elastics.[7] Such compensatory eruption of incisors is often undesirable for patients who also have maxillary vertical excess, a long face, or excessive gingival display.

In recent years, several studies have demonstrated effective molar intrusion in the treatment of anterior open bite patients using temporary anchorage devices (TADs).[8-10] This new treatment strategy resulted in counterclockwise rotation of the mandible, a reduction in the anterior vertical facial height, advancement of the chin, and improvement of the retrognathic appearance of the facial profile without surgical intervention or incisal elongation. However, the overall treatment duration would be prolonged in cases of anterior open bite with anteroposterior discrepancy, as the anterior teeth would be moved after intrusion of the molars using other methods.

In this article, an approach of treatment of an adult patient with dentoalveolar open bite using miniscrews is presented. An efficient method of simultaneous molar intrusion and canine retraction is reported to shorten the treatment duration for correcting open bite with minimal side effects. In addition, information about the long-term stability throughout 4.5 years of retention is provided.

DIAGNOSIS AND ETIOLOGY

A woman 19 years and 5 months of age came to the outpatient clinic of Okayama University Hospital. Her chief complaints were difficulty chewing with the anterior teeth and maxillary incisor protrusion. She had a convex profile and suffered from circumoral musculature strain to achieve lip seal (Fig 1). A decreased overbite of -2.0 mm with Angle Class II molar relationships on both sides was observed. In addition, she had two distinct occlusal planes within the maxilla. Anterior shift of the mandible could be found due to occlusal interference positively associated with the crossbite on the left first premolars. Mild crowding was also observed in the maxillary incisors. The maxillary dental midline was shifted 0.5 mm toward the left of the facial midline. The mandibular dental midline almost coincided with the facial midline (Fig 1). A dental panoramic radiograph revealed asymmetry of both condyles and mandibular ramus without pathological problems in the root structure or the periodontal condition (Fig 2). The patient reported clicking sounds in the temporomandibular joint on the left side. The interincisal distance on maximum opening without pain was 43 mm. Her gingival display on smiling was acceptable.

Compared with Japanese norms,[11] a cephalometric analysis showed a skeletal Class I jaw relationship (ANB = 4.0°) with a low mandibular plane angle (Mp-FH, 24.0°), a small gonial angle (111.0°), and a normal anterior facial height (N-Me = 126.0 mm). The maxillary incisors were slightly inclined labially (U1-FH = 117.0°), and the mandibular incisors were significantly inclined labially (L1-Mp = 110.0°). The maxillary molars were slightly extruded (U6/PP = 27.0 mm) (Table 1).

TREATMENT OBJECTIVES

The patient was diagnosed with skeletal Class I jaw-base relationship, an Angle Class II malocclusion with a low mandibular plane angle, and an anterior dentoalveolar open bite. The treatment objectives were to correct the anterior open bite and establish ideal overjet and overbite, to achieve an acceptable occlusion with a good functional Class I occlusion, and to improve her facial profile. In this case, the maxillary first premolars and mandibular second premolars were extracted to achieve the treatment objectives. The use of miniscrews to achieve intrusion of the elongated maxillary molars to correct the dentoalveolar open bite was planned.

Figure 1 - Pretreatment facial and intraoral photographs.

Figure 2 - Pretreatment lateral cephalogram and panoramic radiograph.

Table 1 - Summary of cephalometric findings.

Variable	Japanese norms for women	SD	pretreatment	post-treatment	2 years post-retention	4.5 years post-retention
Angular (degrees)						
ANB	2.8	2.44	4.0	5.0	5.0	5.0
SNA	80.8	3.61	82.0	82.0	82.0	82.0
SNB	77.9	4.54	78.0	77.0	77.0	77.0
FMA	30.5	3.6	24.0	24.0	24.0	24.0
Go.A	122.1	5.29	111.0	111.0	111.0	111.0
U1-FH	112.3	8.26	117.0	104.5	104.5	104.5
L1-Mp	93.4	6.77	110.0	100.0	102.0	102.0
interincisal angle	123.6	10.64	109.0	131.5	129.5	129.5
Linear (mm)						
S-N	67.9	3.65	64.5	64.5	64.5	64.5
N-Me	125.8	5.04	126.0	126.0	126.0	126.0
Me/PP	68.6	3.71	70.0	70.0	70.0	70.0
Ar-Go	47.3	3.33	55.0	55.0	55.0	55.0
Go-Me	71.4	4.14	72.0	72.0	72.0	72.0
Ar-Me	106.6	5.74	109.0	109.0	109.0	109.0
Overjet	3.1	1.07	4.0	2.5	2.5	2.5
Overbite	3.3	1.89	-2.0	2.5	2.5	2.5
U1/PP	31	2.34	30.0	30.5	30.5	30.5
U6/PP	24.6	2	27.0	25.5	25.5	25.5
L1/Mp	44.2	2.68	43.0	43.5	43.5	43.5
L6/Mp	32.9	2.5	35.0	36.5	36.5	36.5

TREATMENT ALTERNATIVES

The first treatment option involved comprehensive orthodontic-surgical treatment. The patient considered this approach too aggressive and invasive. In addition, she wished to avoid orthognathic surgery.

Another proposed treatment option involved a conventional orthodontic treatment, such as the MEAW technique, without skeletal anchorage. This option would have led to slight extrusion of both the incisors, as described above; nonetheless, the vertical relationship of the patient's incisors and upper lip was considered acceptable before orthodontic treatment.

Miniscrews have a lower surgical burden and cause less discomfort to the patient than traditional procedures. This patient had two distinct occlusal planes, and the extruded maxillary molars were suggested as a main cause of the dentoalveolar open bite. Therefore, intrusion of the extruded maxillary molars was considered to be the a more appropriate treatment choice. This would have led to the autorotation of the mandible in the counterclockwise direction, thereby increasing the overbite and improving the convex profile. After discussing each treatment options, the patient selected the miniscrew-assisted treatment.

TREATMENT PROGRESS

Following the extraction of the maxillary first premolars, two titanium miniscrews (1.6mm diameter; 6mm length; Absoanchor®; Dentos Ltd., Daegu, South Korea) were implanted at the distal alveolus of the maxillary first molars (Fig 3). A transpalatal arch appliance was also placed between the maxillary first molars to compensate for the crown buccal torque that would be caused by the intrusion force. A 0.018-in preadjusted Edgewise appliance was placed on the maxillary molars. After leveling and alignment with nickel-titanium archwires for two months, 0.016×0.022-in stainless-steel archwires were installed to initiate an orthodontic intrusive load of 100g on the maxillary molars (Fig 4A). Simultaneously, 0.018-in preadjusted Edgewise appliances were also placed into the maxillary canines. A 0.016-in stainless-steel archwire was installed and ligated to the miniscrews to induce space closure of the maxillary arch using sliding mechanics (Fig 4B, C). This method for achieving simultaneous molar intrusion and canine retraction enabled the achievement of both a positive overbite and a maxillary canine retraction during four months of treatment without undesirable side effects (Fig 4D). The maxillary occlusal plane was also flattened.

Extraction of the mandibular second premolars resulted in a more retruded position of the mandible. This shift was probably due to the removal of occlusal interference. Class II intermaxillary elastics were used for three months to assist the mesial movement of the mandibular molars.

After removing the appliances and the miniscrews, the maxillary and mandibular teeth were stabilized using a 6-unit lingual bonded retainer and a wraparound-type retainer. The total active treatment period was 21 months.

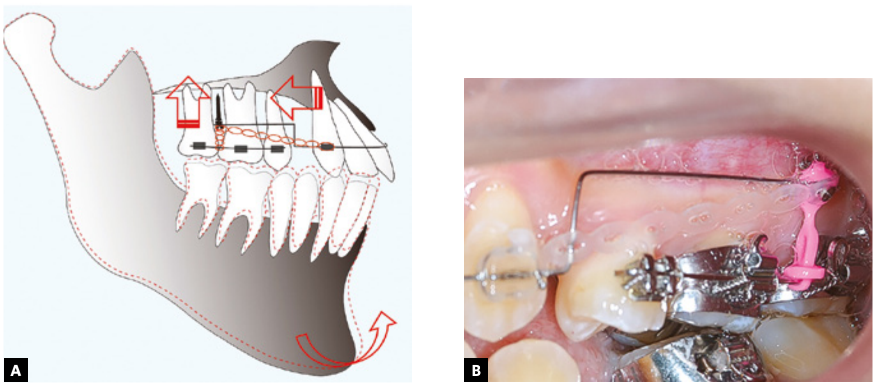

Figure 3 - A) Schematic illustration of simultaneous molar intrusion and canine retraction procedure. (B) Miniscrew implanted at the distal alveolus of the maxillary first molars.

Figure 4 - The treatment progress during simultaneous molar intrusion and canine retraction. (A) At the start of simultaneous molar intrusion and canine retraction. (B) Two months after the start of simultaneous molar intrusion and canine retraction. (C) Four months after the start of simultaneous molar intrusion and canine retraction. (D) Representative intraoral photographs showing gradual changes in the incisor relationships.

RESULTS

The posttreatment facial photographs showed a balanced and harmonious facial profile due to the upper and lower lips retraction, reducing the strain of the mentalis muscle on lip closure. The dental midlines were coincident with the facial midline (Fig 5). A Class I molar relationship and an acceptable interincisal relationship were established on both sides. The posttreatment intraoral photographs also showed well-aligned arches, a flattened occlusal plane, and the good interdigitation of the teeth (Fig 5). Acceptable root parallelism was observed on the panoramic radiograph. Slight apical root resorption was observed, especially in the maxillary incisors (Fig 6). A posttreatment cephalometric evaluation and the superimposed cephalometric tracing showed no marked skeletal changes. The maxillary first molars were intruded 1.5 mm toward the palatal plane, whereas both the maxillary and the mandibular incisors were extruded by 0.5 mm (Fig 7). In an evaluation of the jaw movement with a jaw movement recording system with six degrees of freedom (Gnathohexagraph system, v. 1.31; Ono Sokki, Kanagawa, Japan),[12] a smooth and stable incisal path was found during protrusive or lateral excursion. Furthermore, an

Figure 5 - Posttreatment facial and intraoral photographs.

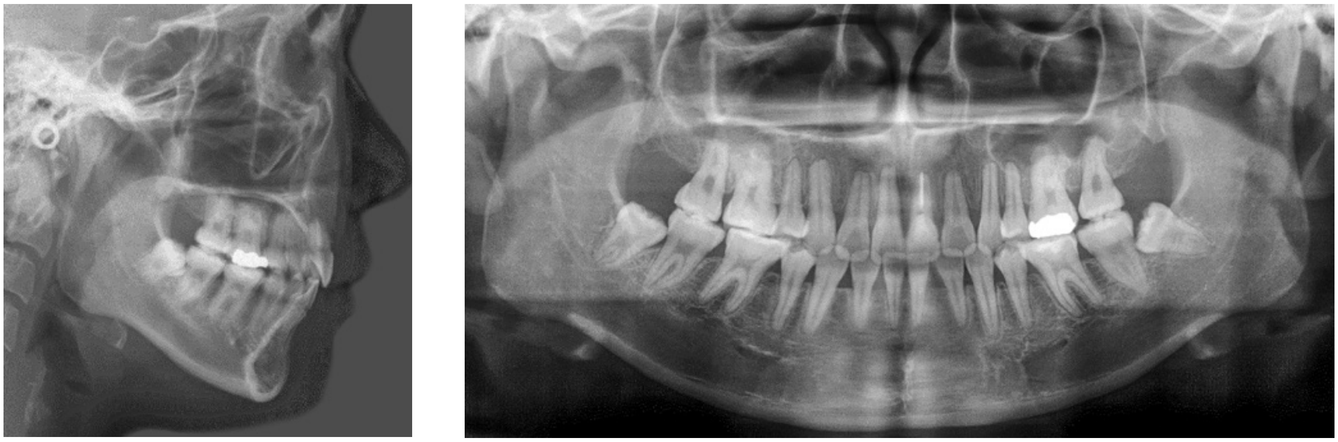

Figure 6 - Posttreatment lateral cephalogram and panoramic radiograph.

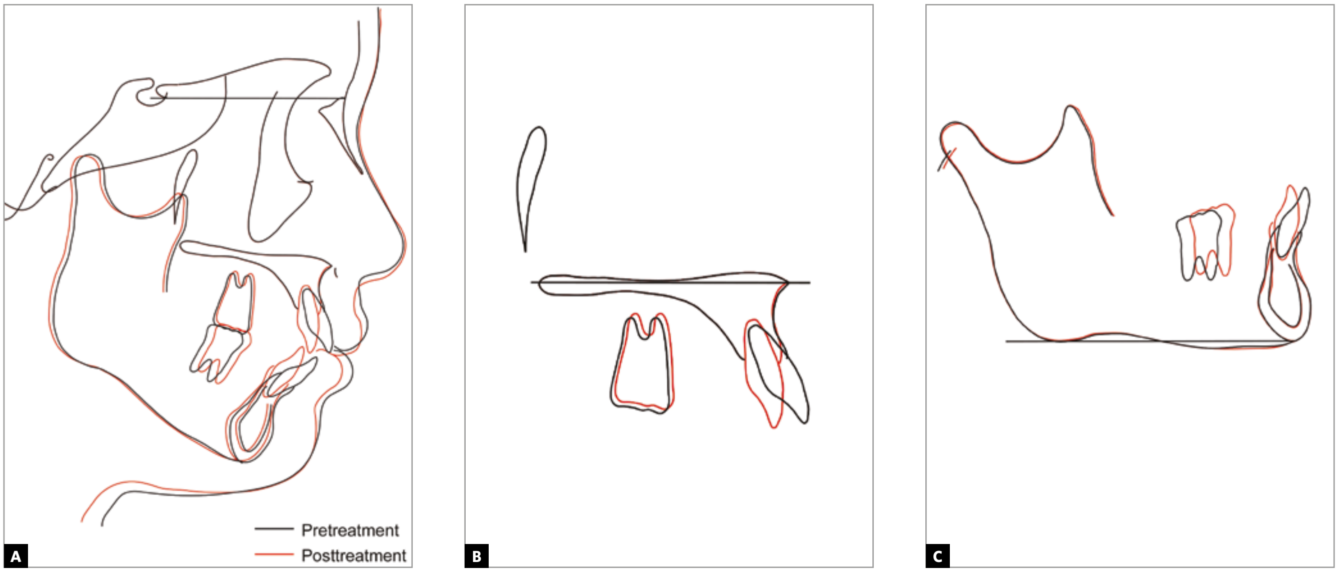

Figure 7 - Superimposed cephalometric tracings showing changes from pretreatment to posttreatment: A) Sella-nasion plane at sella, B) Palatal plane at ANS, C) Mandibular plane at menton.

increase in the condylar movement was also observed on the left side during maximum opening mandibular movement (Fig 8). The interincisal distance on maximum opening without pain increased to 50 mm. After a 2-year retention period, the patient's occlusion was stable, and the favorable facial profile achieved by the orthodontic treatment was also maintained (Fig 9). Post-retention intraoral photographs also showed that the molar and canine relationships, respectively, had been maintained whereas slight reopening of the extraction space between right second premolar and first molar (Fig 9). A cephalometric analysis over the 2-years post-retention period showed a slight forward movement of the maxillary dental arch (Fig 10). In addition, the mandibular incisors were labially inclined by 2° (Fig 11, Table 1). There was no significant difference between the retention at 2 years and that at 4.5 years (Fig 12, Table 1). The acceptable occlusion and ideal overbite and overjet were well maintained, and the patient was satisfied with the treatment results.

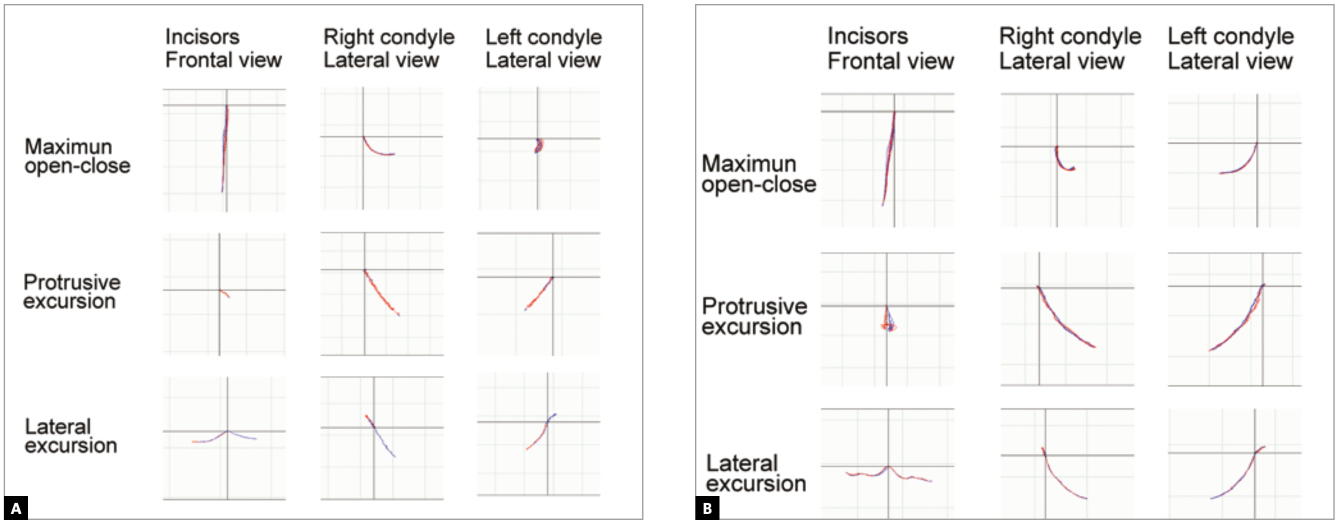

Figure 8 - Condylar movement and incisal paths recorded with the six degrees of freedom jaw movement recording system. The red lines indicate the opening phase, and the blue lines indicate the closing phase: **A**) Pretreatment, **B**) Posttreatment.

Figure 9 - Two-year retention facial and intraoral photographs.

Figure 10 - Two-year retention lateral cephalogram and panoramic radiograph.

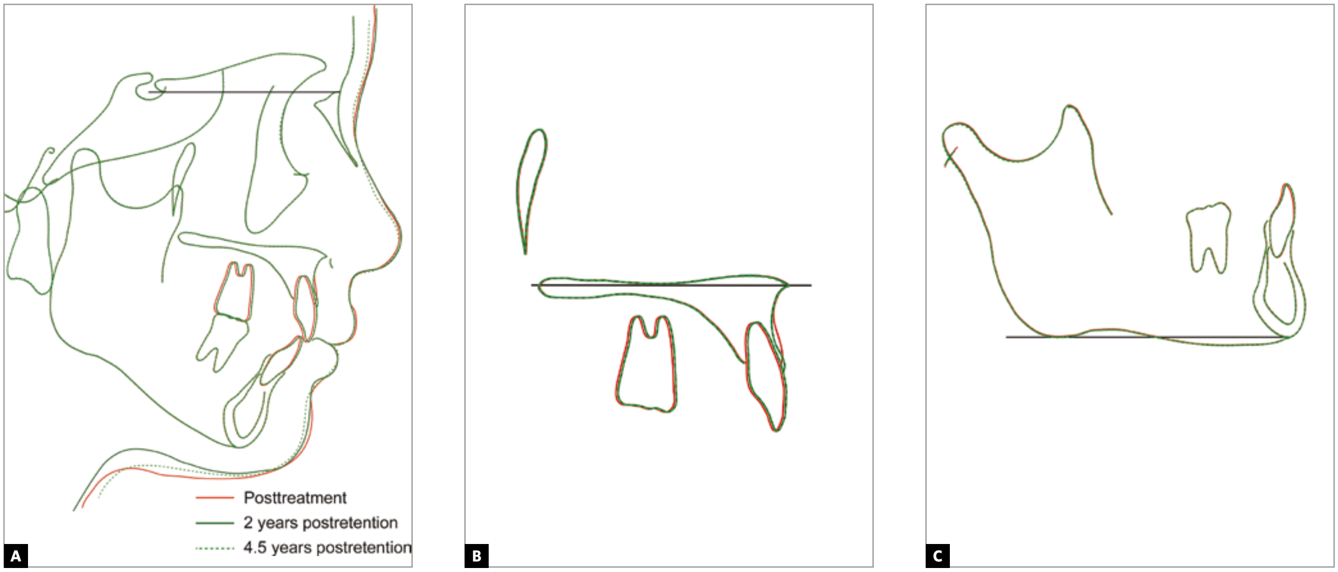

Figure 11 - Superimposed cephalometric tracings showing changes from posttreatment to 4.5 years of retention: A) Sella-nasion plane at sella, B) Palatal plane at ANS, (C) Mandibular plane at menton.

DISCUSSION

The orthodontic correction of the anterior open bite can be achieved by several mechanisms that will result in the intrusion of posterior teeth, the extrusion of anterior teeth, or a combination of both. When the treatment of the dentoalveolar open bite is considered, leveling a maxillary arch by inserting a continuous archwire promotes extrusion of the incisors that is sometimes undesirable in adult patients. This can be explained by the leveling of a maxillary arch with two distinct occlusal planes, which is a common characteristic of a dentoalveolar open bite.[13] The principle of segmental molar intrusion involves minimizing any adverse side effect before leveling and retracting the anterior teeth. However, these separate step-by-step movements of the anterior and posterior teeth can prolong the overall treatment duration.

In the present report, we demonstrated a concurrent approach for managing molar intrusion and canine retraction with miniscrew-aided mechanics. The method, which involved a combination of three segmented archwires, miniscrews, and a transpalatal arch, enabled us to control the anterior and posterior segments independently. This approach is clinically relevant because the vertical and anteroposterior problems can be addressed simultaneously, resulting in a shorter treat-

Figure 12 - Four-and-a-half-year retention facial and intraoral photographs.

ment duration. Our simple design proposed in this study is easy to fabricate, requires no patient cooperation, is less likely to cause soft tissue impingement, and allows clinicians to deliver well-controlled orthodontic force with minimum chair-side adjustment. In addition, a shorter treatment duration may also desirable from the perspective of exposure to possible undesirable side effects of orthodontic treatment, especially the shortening of tooth roots.

The occurrence of apical root resorption is an undesirable but frequent side effect for patients who undergo orthodontic treatment.[14] Lund et al.[15] reported that practically all patients and up to 91% of all teeth showed some degree of root shortening. Some of the risk factors of root resorption are very controversial, but previous reports have concluded that open bite[16,17] and a prolonged treatment duration[18,19] are high-risk factors for apical root resorption. In the present case, no force was applied to move the maxillary incisors in the early stage of the treatment, so there were no potentially detrimental effects on the teeth, such as round-trip movement. Consequently, we think that our system might help reduce the risk of severe root resorption in the upper incisors due to the small amount of time for which Edgewise appliances were mounted in this patient.

Pretreatment records revealed asymmetric mandibular morphology and condylar movement (Fig 8). Although determining the cause of an anterior open bite is complicated, this asymmetry may be related to the functional impairment-induced resorption of the condyles and consequent shortening of the mandibular rami, leading to the development of a Class II anterior open bite.

We used Class II intermaxillary elastics to move the mandibular molars mesially in the later stage of the treatment. Although the patient's mandible did not rotate toward the clockwise direction, this procedure led to the slight extrusion of the mandibular molars. Several reports have described no mandibular advancement or correction of the convex profile by molar intrusion in a single jaw due to the adverse extrusion of molars in the opposite jaw.[20,21] In the present patient, it was not necessary to reduce the facial height because she already had an aesthetically balanced facial height at pretreatment.

Many orthodontists remain concerned about the long-term stability of molar intrusion using TADs. A high prevalence of relapse of molars has been reported within the first[22,23] or second years of retention.[20] Several studies have also examined various risk factors influencing the relapse of open bite correction, such as a long divergent skeletal pattern[24] and non-extraction treatment.[25] Our patient showed acceptable retention up to 4.5 years post-retention, with a low mandibular plane angle and the extraction of four premolars. We believe that our treatment choices contributed to the good stability of the occlusion. Although limited information is available and further studies will be needed to determine the prognosis, these findings provide information to help achieve further favorable stability in this patient.

CONCLUSION

This report described comprehensive biomechanics for achieving simultaneous molar intrusion and canine retraction in the treatment of anterior open bite using miniscrew anchorage. This treatment method enabled the independent control of both the anteroposterior and vertical dimensions with optimum force and minimum side effects. The resultant occlusion and facial profile were stable after 4.5 years. These results suggest that our system is an effective approach in the treatment of dentoalveolar open bite patients with anteroposterior discrepancy for attaining functionally stable occlusion with a short treatment duration.

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