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Writing a scientific paper: Where to start from?

“Our end was just the beginning.” (Yuri Popoff, bassist and composer from Minas Gerais)

It is not our aim, in the next few lines, to make our reader become a contumacious scientific writer. Scientific writing requires practice and there are only a few courses that can guide us to a shortcut. However, there are some useful pieces of advice that I pass on based on the experience I have had as a reviewer, editor and, especially, as an author.

Good scientific research begins with an original idea that is put into practice by means of a robust methodology. If there is a good question, the answer will come in a more interesting way. Once you reliably find the answer, you will only need a low dose of efficient communication. I have come across excellent papers that get lost due to poor writing. However, the opposite is more common. The board of editors will be more interested in correcting minor writing mistakes.

Where to start from? How about the end? Exactly. Start with the conclusion. To my view, one of the most common mistakes is to start writing by the introduction. How can we present something if we do not know what it is? This ordinary path, in my opinion, results from the attempt to make the best of the project that originated the study we write about. As a consequence, we end up with a long introduction that is far from conveying the main message of the research: the conclusion. Thus, starting with the conclusion infuses our mind with the draft of the path that we would like to reveal to our readers.

Afterwards, it is important to keep the conclusion in mind to write the paper in a brief and linear manner. Another common mistake in scientific writing is to be prolix, write more than necessary, especially in the introduction. The researcher intensely lives what he does, sleeping and dreaming about the object of his experiment or observation. And through inebriant osmosis, he starts to believe that everything he writes is utterly important. However, it is worth that the author put himself in the reader's shoes. In this case, less is more. We live in the age of—fast—communication. Short texts and the right words are more appropriate. For this reason, simply read and reread what you have written, and, without fear or guilt, cut everything you think will hinder the comprehension of the text. Many scientific journals of great impact, such as *Nature* and *Science*, require that the authors submit much shorter texts than we are used to in Dentistry field. There is a good reason for that.

Draft. That's it. Draw up a strategic draft, a sketch of all the information you would like to present and define where every item will be within the structure of the text. Remember to keep the conclusion in mind. As you find new interesting information, first ask yourself whether this knowledge is really important for the comprehension of the text. Only after you find an affirmative convincing answer, point out where this questioning will be in the structure of the text.

Within the IMRaD structure (Introduction, Methodology, Results and Discussion), after the conclusion, I usually move forward to the results, followed by the discussion and the material and methods. The introduction is the last part. In all of these parts, do not hesitate to cut the excesses. Researchers usually find it difficult to discard data that did not produce any useful information in their experiment. Similarly, they find it difficult to understand the reason why we have to take a step back in order to search for new information that may be key to the success of the study. Eliminating excessive data greatly facilitates the process of writing a manuscript.

Leave the title to the end. You may even write a temporary title, however, when the text is ready, analyze if the title is suitable to communicate its content, especially what is in the conclusion. We have to understand that the title is the abstract of the abstract, and that is the reason why it should not be too long. Long titles, as well as long texts, instigate readers' disinterest. The title does not have to necessarily communicate everything.

Reread the title of this editorial. All right, this is not a research. An editorial is freer to flow. But analyze it. The text does not reflect on how to start writing a manuscript, only. There are other pieces of information. Should I have mentioned all pieces of information in the title, our beginning would have reached its end right there.

David Normando – editor-in-chief
(davidnormando@hotmail.com)

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INTERPROXIMAL WEAR DOES NOT INCREASE SUSCEPTIBILITY TO DENTAL CAVITY

During orthodontic treatment, interproximal wear is a procedure generally practiced by orthodontists. It is recommended for tooth size adjustment in case of Bolton discrepancy; obtaining space in the arch in borderline cases, being an alternative to tooth extractions; dental contours for elimination of black triangles; transformation of canines in lateral incisors when the latter are absent; among other clinical situations in which it is necessary. Despite its wide acceptance, doubts persist among patients and orthodontists. Would this procedure leave the tooth rougher and more susceptible to dental caries? In the search for an answer, German and Greek researchers developed a systematic review¹ focusing on the evaluation of enamel roughness and its susceptibility to caries with and without interproximal wear. According to the authors, it was difficult to draw conclusions regarding roughness with and without interproximal wear because of the heterogeneity of the studies. As for susceptibility to caries, no scientific evidences nor statistical differences were found among the groups with and without interproximal wear. These results bring us comfort and enable us to convince patients when they are resistant to having this procedure performed.

PALATAL MINI-PLATES AND MINI-IMPLANTS ARE PAINFUL AND UNCOMFORTABLE TO PATIENTS

The importance of skeletal anchorage devices are unquestionable in contemporary Orthodontics. Malocclusions considered of difficult treatment, in the past, are now considered of easy solution with these devices. In this context, mini-plates and mini-implants became popular. The choice between devices is, most of the times, related to the orthodontist's personal preference. Some professionals claim greater power of movement using plates, others say they achieve the same results with mini-implants without a surgical step. However, which one of these devices would be more comfortable to patients? In an attempt to answer this question, Japanese researchers developed a clinical study,² in which they evaluated the pain and discomfort caused by mini-plates and mini-implants after buccal and palatal placement (Fig 1). After installation of the different anchorage devices, the patients answered a questionnaire during 14 days, in which pain and discomfort were scored day by day. The obtained results showed greater discomfort by palatal plates followed by palatal mini-implants and buccal mini-implants. According to the authors, skeletal anchorage devices must be selected in accordance



Figure 1 - Intraoral photographs. A) Mini-plate buccally inserted. B) Mini-implant buccally inserted. C) Mini-implant inserted in the palate (Source: Kawaguchi et al.² 2013).

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with each case, that is, it should not be based on the orthodontist's personal preference. Thus, the patient's opinion must be considered in situations in which different devices will allow the same final results.

ORTHODONTIC TREATMENT IMPROVES ESTHETIC PERCEPTION IN CASES OF AGENESIS OF UPPER LATERAL INCISORS

Agensis of lateral incisors is a common clinical situation in Orthodontics. In the absence of one or two upper lateral incisors, the treatment options vary from space closure with mesialization of canines to space opening before prosthetic replacement. From the perspective of space closure treatment, would this method be well perceived in esthetic terms? And, in untreated cases, which would be the most anti-esthetic situation? In the presence of diastema or in cases of asymmetry? Aiming at obtaining answers to these questions, Italian researchers developed a study³ in which images of cases with agensis of unilateral or bilateral upper lateral incisors, with and without orthodontic treatment, were created (Fig 2). The images were presented to professionals and lay people who were requested to evaluate them from 0 to 10 with regard to esthetics. The results showed that the images in which orthodontic treatment had been performed in the absence of diastemas

and symmetrical were scored as the best by all interviewees. This result reaffirms the need for orthodontic treatment when this dental anomaly is present.

ADDITION OF IODONIUM SALT TO COMPOSITES ALLOWS A SHORTER PERIOD OF LIGHT-CURING

Bonding orthodontic accessories directly to the surface of dental enamel was one of the greatest discoveries in Orthodontics in the last decades. Nowadays, we have access to bonding materials with excellent properties regarding resistance to masticatory forces and orthodontic mechanics, color stability, biocompatibility and fluoride release. Despite so many favorable characteristics, improvements are welcome. One particular improvement would greatly facilitate appliance placement procedures: light-curing within a shorter period time. Bonding materials currently available need light-curing to be carried out for 20 to 40 seconds. It may seem fast, however, considering bonding of all teeth in the mouth, the reduction in light-curing time of each unit would make a significant difference by the end of the day. In search for improvement, Brazilian researchers performed an *in vitro* study in which they developed an experimental composite with different concentrations of iodonium salt, aiming at verifying whether the addition of this



Figure 2 - Simulation of different smiles and treatment options (Source: Rosa et al,³ 2013).

salt would allow light-curing to be carried out within a shorter period of time, without loss of mechanical characteristics of these materials.⁴ The results revealed that adding iodonium salt increases bonding resistance of photo activated composites in 8 seconds when compared to the composite without this salt. This study enables future prospects of developing composites with shorter light-curing time.

DENTAL INTRUSION DOES NOT PROMOTE SIGNIFICANT PULP ALTERATIONS

Pulp alterations associated with orthodontic tooth movement is widely known and documented in the literature. Different tooth movement can promote different pulp alterations. One movement in special is often

associated with alterations of greater magnitude: the intrusion movement. However, what would be the real implication of this movement and of different magnitudes of force on the dental pulp? Chinese authors evaluated these situations in a clinical study⁵ in which intrusive movement was performed in premolars that would be extracted by orthodontic reasons with different force magnitudes (Fig 3). The results showed pulp vitality in the intruded teeth without pulp necrosis. These results are important, however, they must be carefully analyzed and not extrapolated to all teeth in the arch, since the response of incisors may be different from that of premolars. Assessment of anterior teeth is necessary, given that these elements are the most commonly orthodontically intruded.

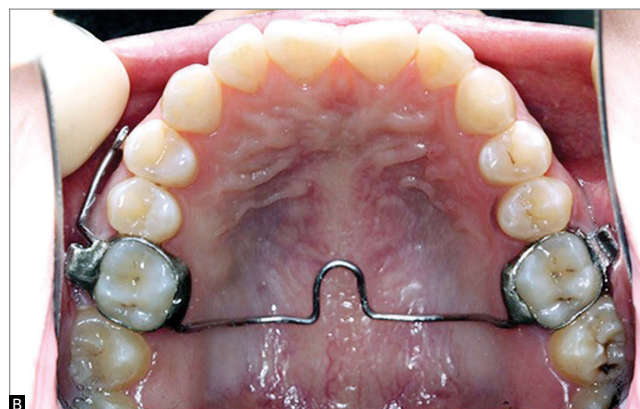


Figure 3 - Appliance used to promote intrusion. **A)** Lateral view of the appliance. **B)** Occlusal view of the appliance composed by transpalatal bar. (Source: Han et al,⁵ 2013).

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Force distribution is more important than its intensity!

Alberto Consolaro¹

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A common question about root resorption is raised in orthodontic practice: What is more important, the intensity of force or its distribution along the root, periodontal and alveolar structures? Diffuse distribution of forces applied to periodontal tissues during tooth movement tends not to promote neither extensive areas of cell matrix hyalinization nor significant death of cementoblasts that lead to root resorption. However, focal distribution or concentration of forces within a restricted area — as it occurs in tipping movements, even with forces of lower intensity — tend to induce extensive areas of hyalinization and focal death of cementoblasts, which is commonly associated with root resorption. In tipping movements, the apical regions tend to concentrate more forces in addition to wounding the cementoblasts due to the smaller dimension of their root structure as well as their cone shape. For this reason, there is an increase in root resorption. In the cervical region, on the other hand, the large area resulting from a large diameter and bone crown deflection tends to reduce the effects of forces, even when they are more concentrated, thus rarely inducing death of cementoblasts and root resorption.

Keywords: Orthodontic forces. Induced tooth movement. Root resorption.

The periodontal ligament is on average 0.25 mm (250 µm) thick, based on measurements that vary from 0.2 to 0.4 mm (200 to 400 µm). It uniformly comprises a membrane of highly specialized fibrous connective tissue of which total volume is occupied in 50% by blood vessels among which venules and capillaries are predominant. These vessels have the thinnest walls and can be easily constricted, which causes quick changes in periodontal ligament blood flow, even when lower forces are applied.

With regard to the forces applied during orthodontic movement, they are usually of low magnitude, even when, in the clinical practice, they are referred to as heavy forces: orthodontic forces cannot be compared

to those of occlusal trauma or dental trauma. In order to move the teeth, it is necessary to excite, stimulate or stress the periodontal ligament cells so as to increase the local production of mediators that are usually released for intercellular communication. Locally increased mediators speed up metabolism and resorptive activity in the periodontal surface of the bundle bone, also known as the alveolar bone or primary and embryonic bone. The increased activity in the area where the ligament is constricted ends up directing tooth movement according to the objective of the clinical force application.¹

In order to attain cellular stress, the force applied to the delicate tissue membrane known as periodontal ligament must be of very low magnitude due to the

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fact that its dimensions are diminutive with many easily constricted blood vessels. Stress can be caused by restricting the volume of blood by means of reducing vessel diameter, or by mechanical deformation of the cell cytoskeleton. Both ways — metabolic or mechanical — mediator liberation synergistically increase in the areas where the forces applied to the periodontal ligament during orthodontic movement act.

As for specialization of the periodontal ligament, it may be considered under many aspects,¹ among which are the functions of:

- 1) Cementoblasts that produce the cementum that is necessary for structural and organizational integration of periodontal collagenous fibers with the tooth root.
- 2) Fibroblasts that orderly produce collagenous fiber structures distributed in such a way that ease and harmonize the forces applied during the function of the tooth, preventing it from touching and being constricted against the alveolar bone in a way that is too harmful for other periodontal structures, such as vessels and nerves.
- 3) Osteoblasts that produce the primary or bundle bone, an alveolar plaster responsible for speeding up the different renovations of the secondary or adult bone that comprises most of the human skeleton. This quick renovation is required by the continued use of tooth and ligament functioning as a joint with the alveolar bone.
- 4) Epithelial rests of Malassez, clusters of cells uniformly and randomly distributed among the periodontal components that constantly release the epidermal growth factor (EGF).¹ This mediator continually keeps resorptive activity of the bone in the periodontal surface of the alveolar process, thus preserving the periodontal space, avoiding alveolodental ankylosis and its most feared consequence: Tooth resorption by replacement.

INTRUSIVE FORCES

Intrusive forces applied to the teeth should be perpendicular to the bottom of the alveolus. Forces that are perpendicular to the bottom of the alveolus are efficiently softened and distributed along the alveolar process by means of the different forms of organization of the collagenous fiber structures in the periodontal ligament.

The periodontal ligament is specifically structured and organized so as to absorb the masticatory forces that tend to be intrusive or perpendicular to the bottom of the alveolar bone.

Intrusive forces are not aggressive to the periodontal tissues during masticatory function. In orthodontic practice, this type of force is not applied to any of the therapeutic procedures used.

Differently from the concept of intrusive forces are the techniques or protocols generally known as intrusive mechanics. This technique aims at producing an intrusive effect on the tooth in the alveolar bone: A real effect that is esthetically and functionally appropriate. Nevertheless, this effect can be produced by tipping movements, taking the position of the tooth in the alveolus, its tipping along the axis and the result of the applied forces into consideration in order to produce the intrusive effect. The applied forces are not at 90 degrees in relation to the bottom of the alveolus. In fact, it is not a pure intrusive force, but forces that lead to a real tipping movement and end up producing an intrusive effect, a real intrusion of the tooth in the alveolus, which is not a result of pure intrusive forces.

BODILY TOOTH MOVEMENT

Bodily tooth movement in the alveolus resulting from forces applied to the crown are considered unreal, given that the entire root would hardly act uniformly, homogeneously and with the same force over the periodontal ligament in the entire surface of the alveolar bone where the force is applied.

Even though it is considered unreal, bodily tooth movement ends up distributing the forces orthodontically applied to the teeth in a more diffuse and less concentrated manner. In other words, the forces applied to the teeth in order to produce a bodily movement are better distributed in the periodontal and alveolar tissues. Constriction of periodontal vessels and, as a result, blood flow restriction as well as deformation of cytoskeletons are eased while the concentration of mediators is modulated in order to prevent the risk of cellular death and extracellular matrix hyalinization.

TIPPING FORCES

The forces intentionally applied to produce tipping movements tend to be concentrated within a smaller periodontal area. For this reason, the risks of collapsed blood

vessels, cellular death and extracellular matrix hyalinization are much higher. The tooth root has the cementoblasts as protectors of its structural integrity. Without receptors for the bone resorption mediators in their membrane, the cementoblasts are subject to tissue phenomena observed in tooth movement. When the cementoblasts eventually die due to forces that not only restrict the vessels that feed them, but also lethally deform them, there will be root resorption with denudation and exposure of the tooth surface facing the periodontal ligament.

The orthodontic forces tend to concentrate in the tooth apices due to their cone-shaped configuration, even when the objective is to produce bodily movement. In other words, when the forces act within a limited area, they tend to concentrate and increase the possibility of eliminating cementoblasts, thus increasing the frequency of root resorption in this region.

FORCE DISTRIBUTION AND INTENSITY IN ROOT RESORPTION

With regard to orthodontically applied forces, the clinician must focus more on their distribution than on their intensity, especially with regard to induction of root resorption. If bodily movements are considered as a priority, even though it is known that they cannot be fully produced because there will always be some degree of tipping, the forces will be better distributed than when tipping movements are produced first.

Tipping movements tend to concentrate forces in the apical and cervical regions, in which case extracellular matrix hyalinization areas are established and some or many cementoblasts die. Tipping movements are more associated with apical root resorption.

The conical shape of the apical third favors greater concentration of forces in this region, with death of cementoblasts happening more often than in the cervical third. Larger diameter and area of the cervical third as well as the greater capacity of deflection of the bone crest ease the effects of forces concentrated in tipping movements. In the apical third, in tipping forces, there is no bone deflection and the root

structure is narrower and thinner. In this region, the risks of collapsed blood vessels are higher than in the cervical region. These are the reasons why root resorptions in orthodontic practice are more common in the apical third and rarer in the cervical third.

When the main factor concerning the pathophysiology of resorptions is questioned, whether it is force intensity or distribution, it should be highlighted that distribution plays a more important role. Light, but concentrated forces promote resorption; while intense, but well distributed forces do not damage the periodontal structures so far as to cause death of cementoblasts, the initial phenomenon of root resorption.

FINAL CONSIDERATIONS

Diffuse distribution of forces applied to periodontal tissues during orthodontic movement tends not to promote either extensive areas of cell matrix hyalinization or significant death of cementoblasts that lead to root resorption. However, focal distribution within a restricted area, even in cases of lower intensity forces, tends to induce extensive areas of hyalinization and focal death of cementoblasts, which is commonly associated with root resorption.

The apical regions tend to concentrate even more forces and wound the cementoblasts due to the smaller dimension of their root structure as well as their cone shape. For this reason, they are frequently associated with root resorption. On the other hand, in the cervical region, the large area resulting from large diameter and bone crown deflection tend to reduce the effects of forces, even when they are more concentrated, thus rarely inducing death of cementoblasts and consequently root resorption.

Clinical and image studies comparing techniques and shape of root and apex, as well as the different types of movements and forces, could support in an applied and direct manner the thoughts and insights on “orthodontic force intensity and distribution and its effects on root and periodontal structures: A comparative study according to different therapeutic protocols.”

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What is the meaning of this lowercase “p”?

José R. P. Lauris*

Most health professionals are resistant to statistics. There is nothing inconsistent about it: if they liked Mathematics as a profession, they would have chosen a career in the exact sciences.

Clinical dentists are not different: most of them prefer to avoid greater proximity to, and as a consequence, understanding of statistics. Undoubtedly, many statistical procedures involve complex and difficult-to-understand calculation for those who do not have expertise in this area.

It turns out that, similarly to the fact that using a car does not require knowledge of the car's intricate mechanism, electrical and electronic components, using statistics to interpret the results of a research does not require knowledge about details of the formulas that have led to these results.

An important concept in the interpretation of an article is to distinguish “descriptive statistics” and “inferential statistics.”

Descriptive statistics are all procedures that aim to describe the data collected in the sample. The main statistical resources in this area are: tables, graphs, parameters such as the mean, standard deviation, correlation coefficient, absolute frequency (n), and relative frequency (%). Inferential statistics appear in the article as the p-value (probability), helping us draw conclusions from survey results obtained from the population represented by the sample.

As an example, suppose the researcher wants to investigate the effect of certain orthodontic treatment on

the value of patients' SNA angle. When an article says that the pre-treatment mean SNA of a sample of 30 subjects is equal to 81.5°, this is the average value found by the researcher in the study sample. Assuming that the post-treatment mean is 80.5°, the researcher can conclude that, among the patients treated during the study, there was a mean reduction of 1° in the SNA. These results are descriptive statistical procedures. Descriptive statistics describe the data collected and, therefore, refer only to subjects in the research. This description does not involve any calculation of probability, since probabilistic error is not involved at all. Thus, it can be concluded that the treated patients had a mean reduction of 1°, because the researcher has observed this.

In a survey, however, we want to reach a conclusion not only for those who participated in the survey (sample), but also for all other subjects who did not participate in the study (population) but may need the kind of treatment studied. To make a statistical inference is to draw a conclusion for the population based on the results obtained from the sample. We intuitively make inferences in our day-to-day lives. For example, when a person has been dating for two years and decides to get married, that person is making an inference and acting upon that inference. That is because the person has evaluated those two years (sample), considered as good, and concluded that living for life together (population) will be good too. The problem is that, by making an inference (extrapolating the results from a sample to a population),

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we run the risk of making mistakes because we are trying to form conclusions about a larger group of elements than the one we have studied in the research. In the case of dating/marriage, we have made an inference and may be wrong: we may conclude that marriage will be good, and it may turn out not to be. In our daily lives, when we make an inference, we do not know our chances (probability) of being wrong.

What inferential statistics procedures do is simply to calculate the probability of being wrong by making an inference for the population. Therefore, in the articles, “p” simply stands for the probability of being wrong by making a certain inference about the population.

In the case of SNA, we can say that, in the treated sample, there was a reduction in SNA. The question is whether we can conclude that the treatment will alter the mean SNA of the population that can be treated by that treatment, not only the population included in the sample. If we conclude that treatment alters the population’s SNA, we may be wrong: it may be that this has happened in the sample, but will not be repeated in other patients. What inferential statistics do is to calculate the probability of being wrong (p) by saying, based on the survey sample, that the treatment alters the SNA angle of the potentially treated population.

To calculate probability, statisticians use data obtained in the sample, such as mean, standard deviation, and sample size. In our example, the calculation would give as a result close to $p = 0.237$ (23.7%). This means that, if we conclude that the treatment changes the population’s SNA, we have a 23.7% chance of being wrong. What the researcher has to do is decide, based on the statistical calculation, whether he will say that treatment alters the SNA. One researcher may find that 23.7% is a small chance of error and decide to conclude that the treatment alters the SNA; another researcher may find that the risk of error is too big and not conclude that the treatment alters the SNA. In order to have a standard for decision making, in biology in general, the adopted threshold of p value is 5% (0.05).

We name this threshold “significance level.” Thus, if the p-value obtained is less than 0.05 (probability error for concluding a result for the population which is less than 5%), we conclude that what happened in the sample (SNA was changed by the treatment) is what should happen in the population. But if the p-value is greater than 0.05, we do not conclude that what happened in the sample will necessarily occur in the population. In our fictional example, as the p obtained (23.7%) is higher than 5%, we would consider it impossible to conclude that the treatment would alter the SNA. Another way of expressing the conclusion is that, if “p” is lower than the significance level (5%), we say that the difference found is statistically significant — that is, statistically speaking, there is a difference between pre-treatment and post-treatment.

As a rule, the lower the p-value is, the less the chance of error when we conclude that what has happened in the sample should happen in the population.

“Statistical tests” are the procedures for calculating the p-value. There are lots of statistical tests (e.g. t-test, analysis of variance, chi-square test, correlation test) because the best way to calculate probability varies according to several factors such as variable type, number of study groups, and whether measurements are made on the same subject or on different subjects.

No matter which test is used to calculate “p”, the interpretation of “p” is the same for all types of research and every statistical test used.

Thus, every time you, the clinician, find a p-value in an article, do not be intimidated. You can interpret it without knowing what calculation was made that resulted in that value. If p-value is less than the significance level (usually 0.05), one can extrapolate to the population the results that were found in the sample. And what was found in the sample? Simply read the results of the descriptive statistics presented.

An interview with

Kazuo Tanne

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- » PhD in Orthodontics, University of Osaka.
- » Head of the Asian Orthodontic Society.
- » Former Head of the Department of Orthodontics and Craniofacial Development Biology, University of Hiroshima, Japan.



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Professor Kazuo Tanne has a degree in Dentistry by the University of Osaka where he also received the title of PhD in Orthodontics. From the 1st of July, 1993 to the 31st of March, 2013 he was the head of the Department of Orthodontics and Craniofacial Development Biology at the University of Hiroshima, in Japan. Professor Tanne has been the head of the Japanese Association of Cleft Lip/Palate, and nowadays is the head of the Asian Orthodontic Society which comprises 18 orthodontic societies in the Asia/Pacific area. He has published more than 700 articles and more than 60 books and/or chapters about many different topics. Professor Tanne has conducted interesting researches that focus on temporomandibular disorders, tooth cryopreservation, cleft lip/palate, molecular/cell biology and genetic engineering for bone repair. I am honored to say that I was advised by Professor Tanne during my Doctorate in Orthodontics between 2006 and 2010. During that period, I had the opportunity to fulfill my expectations towards the excellence of education provided by the University of Hiroshima as well as by Professor Tanne who also proved to be a great human being with a noble heart. We have become great friends and fortunately I had the chance to learn much more than Orthodontics. Tanne Sensei, as he is known in Japan, has a deep admiration for Brazil and the Brazilian culture. He has been in Brazil in three occasions, when he made friends in many different locations.

Emanuel Braga Rêgo

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

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Professor Tanne, you have been in Brazil on three different occasions during when you had the chance to attend conferences and exchange experiences with renowned Brazilian universities such as the Federal University of Rio de Janeiro (UFRJ), State University of São Paulo (UNESP) in Araraquara, State University of Campinas (UNICAMP) in Piracicaba and the University of Brasília (UnB). Additionally, you have advised six Brazilian orthodontists in the postgraduate program of the University of Hiroshima. In this context, what are your impressions of Brazilian Orthodontics? (Emanuel Braga Rêgo)

I have been to Brazil three times to attend scientific events. Among these events, the 49th International Dental Meeting, in Araraquara, was the most impressive, given that it was my first time in Brazil. Moreover, I had the opportunity to teach a one-week course for some dental students at UNESP, which was highly advantageous to them. In this opportunity, I have to admit I found the knowledge of Brazilian students to be a little inferior in comparison to the Japanese, especially in regard to scientific research. After that, I attended to other events: One was held in Campinas, in April, 2006, during which I had the opportunity to teach a course to the students of Orthodontics at UNICAMP, whereas the other one was held in Fortaleza, in September, 2009 (CLEFT). After these two experiences, I noticed that students' level of knowledge had increased substantially in clinical and scientific terms. Nevertheless, I would like to suggest that all orthodontists, especially those involved with education, promote basic researches that can turn into useful evidence for the development of new therapeutic systems and techniques available for day-to-day Orthodontics. I also would like to highlight the importance of scientific exchange with other countries as a practical and quick way to produce the best performance in research. Incorporating young orthodontists/scientists who have received a doctorate title or have attended training programs abroad into Brazilian universities is undoubtedly a very positive measure.

Professor Tanne, could you briefly explain the educational process students go through in Japan in order to become an orthodontist? (Emanuel Braga Rêgo)

Before explaining the educational process, I would like to present the current status of Orthodontics in Japan.

The Japanese Orthodontic Society (JOS) is the official association in Japan. Up to February, 2012, it had 6,375 members. We can make an estimate based on the general population in Japan, which is of approximately 120 million people. The number of colleges authorized to offer postgraduate courses in Orthodontics is 29. The number of orthodontists certified by the JOS is 2,739 or 43% of all members (JOS members do not necessarily hold a certificate of Orthodontics). The number of orthodontists who hold a specialist certificate (a title that is similar to the Board certification) is 298, which corresponds to 5% of all members or 11% of all certified members. In other words: In Japan, the orthodontic certificate issued by JOS requires a 5-year postgraduate course and finishing of 30 cases, out of which two are selected for an oral test. Subsequently, there is a more specific certification that is called specialization: The applicant must present ten cases that have been treated with at least two years in retention and, then, undergo another evaluation. Only those who hold an orthodontic certificate issued by JOS are allowed to apply for the title of specialist.

Professor, Hiroshima is well known in Brazil for the atomic attack it underwent during the Second World War. After this interview, at least for the orthodontic community, Hiroshima will also be known for its excellence in orthodontic education and scientific production. Could you highlight the most relevant topics that are being studied at the University of Hiroshima nowadays? (Emanuel Braga Rêgo)

Since I have been promoted to head of the Department of Orthodontics in Hiroshima, I have always tried to educate young students with clinical training and clinical thinking towards research. Hence, I have always required that we develop relevant scientific topics, even though they wished to act as clinicians, only. As a result, three students have become professors and head of their respective departments in other universities, 81 students have received a PhD title whereas 102 have received the orthodontic certificate. The topics we are currently studying are as follows: 1) biomechanical, biological and molecular mechanisms, as well as therapeutic principles, of temporomandibular joint osteoarthritis; 2) cryopreservation of cells and tissues used in

the teeth bank as well as for tissue regeneration in the treatment of bone defects in cleft palate patients; 3) root resorption prevention and repair with therapeutic low intensity ultrasound; 4) association between malocclusion, breathing and sleep disorders, evidencing that orthodontic treatment can improve one's quality of life; 5) application of amelogenin, a protein of tooth enamel, to repair tooth-surface defects.

Initially, I would like to compliment you for the excellent job you have done in education and for the important researches you have developed at the University of Hiroshima, which greatly contributes to the development of Orthodontics. I would also like to compliment the Dental Press Journal of Orthodontics for the excellent choice for this interview. In Brazil, we have reference centers for the treatment of cleft patients. These centers have a multidisciplinary approach, i.e., they work with dental, orthodontic, surgical and psychological treatments. Specifically with regard to orthodontic treatment of cleft patients, I would like to ask: 1) Can these patients receive orthodontic treatment in private clinics, i.e., not in reference centers? 2) Briefly, what is the logistics for these patients in Japan?

(Fábio Lourenço Romano)

In Japan, the treatment for cleft lip/palate patients is covered by health insurance; therefore, they only have to pay for 30% of the costs of surgery and orthodontic treatment. Additionally, only certified orthodontists are allowed to treat cleft lip/palate patients, whether in hospital or specialized private clinics. On JOS website, there is a list of certified orthodontists and patients have free access to this information. With regard to treatment, the general protocol requires that patients be pre-surgically treated with the Hotz appliance. Afterwards, cleft lip and palate cosmetic surgeries are carried out at the age of 3 or 4 months old as well as at 18 months old. Orthodontic treatment is performed immediately after treatment for maxillomandibular discrepancy and anterior/posterior crossbite repair. At around 9 years old, during initial orthodontic treatment usually performed before eruption of permanent canines, secondary bone graft is carried out to repair

the bone defect in the cleft area. Finally, once permanent dentition is complete, patients undergo orthodontic treatment with fixed appliances in order to have their dental arches lined up, in addition to attaining the most satisfactory occlusion. In this phase, orthognathic surgery may be proved necessary for asymmetry and severe bone discrepancies repair. Dental agenesis is corrected by means of fixed prostheses or implants placed after body growth is complete.

Rapid maxillary expansion associated with protraction of the maxilla is one of the treatment methods employed for anteroposterior maxillary deficiency in growing patients, especially in cleft patients. Based on your experience, do you consider this treatment protocol efficient and stable? (Fábio Lourenço Romano)

Rapid maxillary expansion is very useful for posterior crossbite correction. However, before expansion, it is necessary to diagnose the anteroposterior maxillomandibular relationship. Should significant discrepancy be found between the bone bases, crossbite will necessarily be present, even if the transverse dimensions of the maxillary dentition are normal and the apical base is within normal standards and in harmony with the mandible. In this context, overexpansion of the maxilla is unstable or inconvenient for future treatment with fixed appliances. Based on the aforementioned considerations, we initially treat the anteroposterior relationship of children with orthopedic appliances, whereas adult patients undergo distraction osteogenesis surgery (assessed from 12 years old on).

Do you believe that autograft of mesenchymal stem cells associated with hydroxyapatite carbonate will be successfully used for bone regeneration of cleft palate in the future? (Fábio Lourenço Romano)

I appreciate your interest in bone regeneration with mesenchymal stem cells, since it is a relevant topic about which we have been studying in our department at the University of Hiroshima. Firstly, we conducted an *in vitro* study to understand the proliferation and differentiation of these cells and also to assess whether these abilities can be controlled by

addition of some chemical mediators such as cytokines and growth factors. Afterwards, we conducted *in vivo* studies. Artificial defects were made to the parietal bone of growing rats and mesenchymal stem cell cultures were transplanted to these defects. After 8 and 16 weeks, bone regeneration and sutural structures were noticed. Additionally, we conducted a similar experiment with Beagle dogs in which bone defects were made to the maxilla so as to simulate cleft palate. The latter was posteriorly filled with mesenchymal stem cells and hydroxyapatite carbonate. The results demonstrated prominent bone regeneration in the bone defects. Finally, we were able to prove that mesenchymal stem cells cryopreserved with the new freezing system (freezer with magnetic field) can also be successfully used for bone regeneration.

Based on these studies, we are confident that mesenchymal stem cells transplantation will become a great tool for the treatment of bone defects in cleft palate patients. Moreover, it is evident that the psychological stress to which patients are subjected due to the several surgeries they have to go through will certainly be minimized with this bone regeneration therapy. In our university, clinical trials have been made with regard to the use of this therapeutic method in cleft palate patients.

It is a great pleasure and an important opportunity for me to ask a few questions to you, Professor Tanne, a renowned scientist who studies the pathophysiology of the temporomandibular joint. The identification of clinical signs is very important to diagnose temporomandibular disorders (TMD), however, such information is not always well understood by the clinician. In addition to TMD clinical signs, which methods have proved to be the most efficient in the diagnosis, treatment and follow-up of orthodontic patients with temporomandibular disorders at the University of Hiroshima?
(Rogério Lacerda dos Santos)

TMDs are known as multifactorial diseases, therefore, a differential diagnosis with appropriate methods is required. Furthermore, we have to pay special attention to the fact that orthodontic patients have a considerably high prevalence of TMD, and do not usually identify the problem before orthodontic treatment onset.

A differential diagnosis of TMD is generally done by means of clinical, functional and imagiological examinations. Additionally, modern biochemical tests are available, especially for patients with suspected temporomandibular joint osteoarthritis.

As for the diagnosis of TMDs, the clinical examination firstly aims at tracking the following four main symptoms: joint pain, noise, muscular sensibility and difficulty in mouth opening. With regard to noise, crackling must be differentiated from clicking for an appropriate diagnosis. A click generally suggests anterior disc displacement with reduction. Crackling, on the other hand, suggests a pathologic condition that is more severe than clicking, and it is associated with anterior disc displacement without reduction. Difficulty in mouth opening is established when the degree of opening is less than 35 mm for adolescents and less than 40 mm for adult patients.

Should any sign or symptom be detected, the patient is subjected to the functional examination. For this examination, occlusal patterns such as occlusal force, tooth contact area, muscle activity and fatigue as well as condylar movement, are analyzed. Among these patterns, the analysis of condylar movement is the most valuable for TMD diagnosis in terms of intra-articular pathology identified by the pattern and course of the condylar movement. At our clinic, the axiograph and a 6-degree jaw tracking device are used to analyze condylar movement. The use of these devices allows us to identify four different movements. If the condylar course is smooth and the linear length is greater than 10 mm, it will be considered normal. The 8-shaped pattern represents the crossing between the courses of opening and closing, which reflect the beginning of clicking noises between the disc and the condyle. Therefore, 8-shaped pattern sagittal condylar movement suggests anterior disc displacement which is divided into early, intermediate and late, according to the crossing point of the course that is affected by the degree of disc displacement. Late disc displacement is considered more difficult to treat due to being more severe. The other types of disc displacement are more restrict or mixed, and are generally related to severe pathologies and internal joint disorder.

Imagiological exams such as tomographies and magnetic resonance are recommended for patients with suspected joint internal disorder. Tomography imaging is

useful to measure not only the joint spaces, but also the condylar position in the glenoid fossa. Additionally, it is used to detect condylar bone disarrangements. As for magnetic resonance, it is able to assess the level of displacement and the arrangement of the disc. At our clinic, the criterion proposed by Wilkes has been used for a differential diagnosis of internal disorders. The status of intra-articular pathology is classified into six stages. Stage zero: normal; stages I and II: mild disc displacement with reduction. It is important to highlight that no other significant mechanical symptoms can be recognized, except for the reciprocal click which is observed in stage I of the pathological status. From stage III to V, both disc displacement without reduction and condylar deformity can be observed.

It has been proved that the majority of TMDs can be diagnosed by means of several exams; therefore, I recommend that all aforementioned steps be taken in order to achieve a differential diagnosis and, thus, prevent unexpected TMD conditions, such as temporomandibular joint osteoarthritis, which leads to unsuccessful orthodontic treatment with reasonably unstable results.

Temporomandibular disorders are functional disorders of the masticatory system with complex

and multifactorial etiology. Different therapies are referred to in the literature for the treatment of these disorders, for instance, occlusal, pharmacological, physiotherapeutic and psychological therapies. What is your opinion about the applicability of occlusal therapy performed by means of relaxation splints in patients with temporomandibular dysfunction and in need of orthodontic treatment? (Rogério Lacerda dos Santos)

The best therapeutic strategies are chosen according to the signs and symptoms of TMD. The Japanese Society of TMD provides a treatment protocol for each type of TMD according to the following symptoms and intra-articular pathologies:

- » Type I: Disorders of the masticatory muscles.
- » Type II: Disorders of ligaments and soft tissues.
- » Type III: Disorders of articular disc or condyle.
 - Subtype III a: Anterior disc displacement with reduction.
 - Subtype III b: Anterior disc displacement without reduction.
- » Type IV: Temporomandibular joint osteoarthritis with progressive condylar resorption.

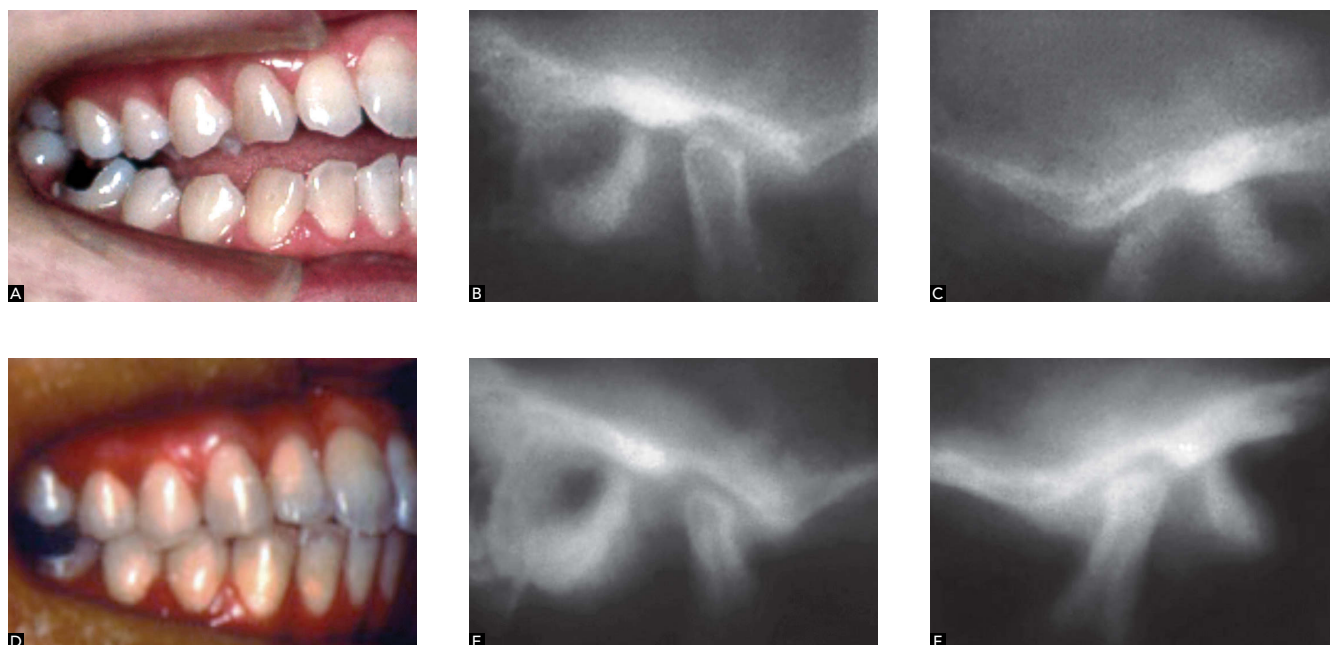


Figure 1 - A, B, C) Pre-treatment: Abrasion of anterior teeth suggests recently developed open bite, probably originating from temporomandibular joint osteoarthritis. Special attention must be paid to the right and left condyles. **D, E, F) Post-treatment:** Unexpected reshaping of condyles. This phenomenon is a clinical evidence of regeneration or adaptation that can occur when stable and satisfactory occlusion is achieved by means of orthodontic/prosthetic treatment.

For types I or II, the relaxation splint is recommended to eliminate the pain in the tissues, given that it promotes decompression. Pharmacological intervention may be effective for symptomatic relief in some patients. After regression of symptoms, occlusal orthodontic treatment or occlusal treatment with prosthetic rehabilitation must be performed in cases in which the malocclusion is the cause of TMD.

As for subtype III a, the anterior repositioning splint is recommended to correct the position of the disc as well as the condyle. After repositioning the disc and the condyle, orthodontic/prosthetic treatment must be performed in order to keep the new condylar position, given that the result obtained with the therapy performed with splints is unstable and often relapses. As for types III b and IV, repositioning the disc in the condyle is considered a difficult task, therefore, it is wise not to contribute to the progression of intra-articular pathology. In this case, occlusal reconstruction may be recommended. In fact, our cases have demonstrated that progressive condylar resorption may be cured or repaired after a stable occlusion is achieved in association with normal condylar positioning.

Based on your clinical experience, especially with regard to patients with open bite, deep bite and posterior crossbite with temporomandibular disorder, how often do relapses occur and/or temporomandibular disorders persist in these patients? Would these relapses be more related to the complex etiology of the relationship between malocclusion and TMD or to inappropriate orthodontic treatment? (Rogério Lacerda dos Santos)

This is a difficult question to answer because the relapse of malocclusion is different from the relapse of TMD. Based on my experience, the relapse of malocclusions orthodontically treated are due to deficient retention, little patient's cooperation with regard to the use of retainers, persistence of deleterious habits related to the etiology of the malocclusion (mouth breathing, tongue protrusion) and unsatisfactory treatment. Relapse of TMD occasionally occurs, however, it may be difficult to identify the reason why it occurs. It has been demonstrated that

the relapse of TMD or progression of mild TMD into temporomandibular joint osteoarthritis, during and after orthodontic treatment, clearly suggests posteroinferior mandibular displacement followed by condylar resorption, in addition to Class II relationship with open bite as well as open mandibular angle, which is more severe than the original malocclusion. Based on the aforementioned considerations, it is expected that orthodontists correctly assess the patient, ensuring that the joint is healthy before orthodontic treatment onset.

It is a great honor to have the opportunity to interview Dr. Tanne about a very interesting and relevant subject matter: teeth bank. Researches on tooth cryopreservation and reimplantation have been brilliantly conducted at the University of Hiroshima and will certainly contribute not only to dental rehabilitation, but also to improve patients' quality of life. Professor Tanne, could you briefly explain how it all started and describe the current status of the University of Hiroshima teeth bank? (Matheus Melo Pithon)

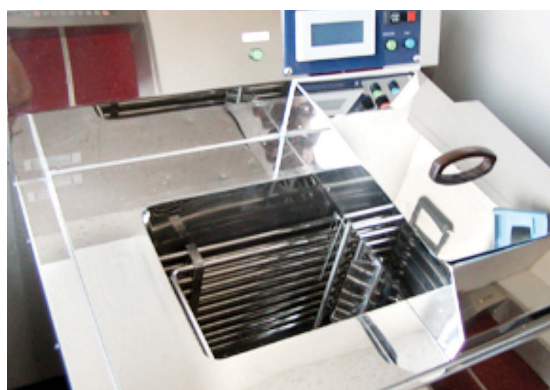
I greatly appreciate your interest in tooth cryopreservation. Tooth transplantation is covered by health insurance in Japan and it is considered a conventional treatment method employed to replace lost teeth. However, tooth transplantation must be carried out immediately after tooth extraction. Tooth extraction is well accepted and is part of many orthodontic treatment plans, for instance, in cases of great tooth/bone discrepancy. Transplantation is not necessary in the majority of these cases, yet the extracted teeth are discarded as hospital waste. In this context, we have developed an advanced system of cryopreservation under magnetic field called CAS (Cells Alive System). To validate the CAS system, we initially conducted an *in vitro* study with a culture of fibroblasts originating from the periodontal ligament in order to exam the survival and proliferation rates of the cryopreserved cells after thawing. The results demonstrated survival and proliferation rates that were satisfactory for transplantation. Afterwards, an *in vitro* study was conducted to assess the feasibility of transplanting cryopreserved teeth in rats. Upper central incisors that had been

immediately reimplanted served as control. The results did not reveal the development of ankylosis and the root resorption rate did not present any difference among the teeth that served as control. Subsequently, with permission of the Japanese Ministry of Health, we transplanted a cryopreserved tooth in a 28-year-old female patient, the first experiment of this nature in the world. The results were excellent, with significant regeneration of periodontal tissues. So far, there are more than 1,800 cryopreserved teeth in our teeth bank. Among these, approximately 130

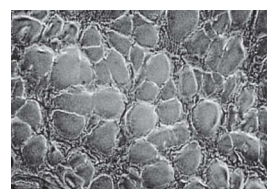
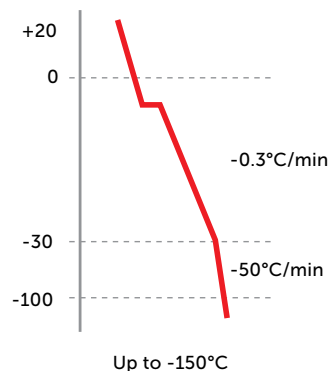
teeth have returned to their original patients with a success rate of 95%. Therefore, it is reasonable to conclude that our teeth storage system is extremely useful to preserve teeth that have been extracted due to orthodontic indication. Additionally, the application of this technology in tissue engineering, particularly with regard to the preservation of other types of tissues and cells, such as stem cells, seems to be highly promising. In fact, we have demonstrated that cryopreserved mesenchymal stem cells induce bone repair in bone defects created in growing rats.

Cryopreservation of teeth

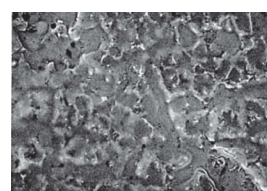
0.1 mT magnetic field



Freezing program



Programmed freezing

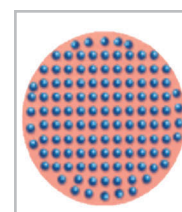
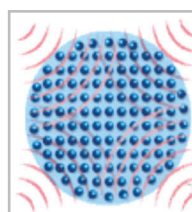
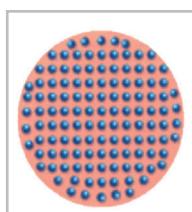


Conventional freezing

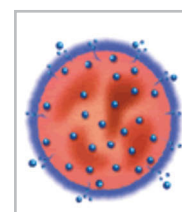
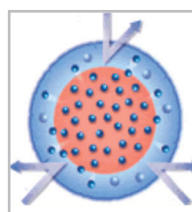
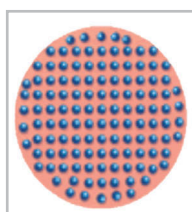
Programmed freezing

Electron microscopy of a rat's masseter muscle

Programmed freezing developed in our study



General programmed freezing



Molecule of water before freezing

During freezing

Molecule of water after thawing

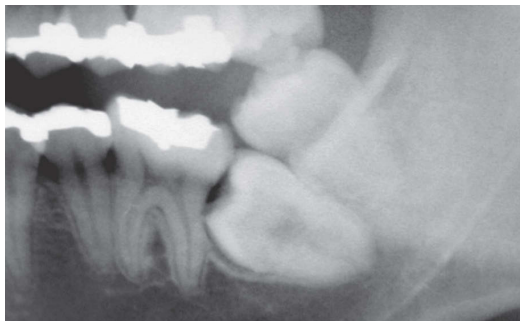
Professor, could you briefly explain the cellular mechanism involved in the preservation of a tooth? Are there any studies regarding orthodontic movement in sites that have received cryopreserved cells? (Matheus Melo Pithon)

In the magnetic field obtained with the CAS freezer, the molecules of water inside the cells vibrate and are uniformly aligned. Therefore, at thawing, they do not destroy the cell wall, whereas in the conventional freezer the molecules of water freeze, forming

clusters that, when undone at thawing, destroy the cell wall. This fact results in low survival rate and low cell proliferation, which leads to unsuccessful transplantation due to poor tissue regeneration.

To assess the metabolic activity of mesenchymal stem cell regenerated bones of Beagle dogs, we conducted a study in which teeth were subjected to movement within the new regenerated bone tissue. Tooth movement rate was similar to the control groups, thus suggesting an equivalent metabolic function.

Transplantation of a cryopreserved tooth (28y-1m female patient)



Before treatment



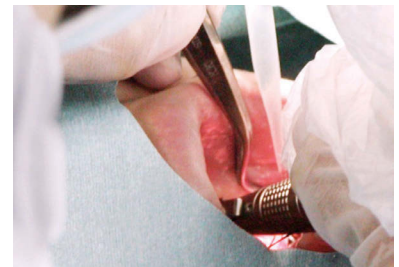
Premolar extraction



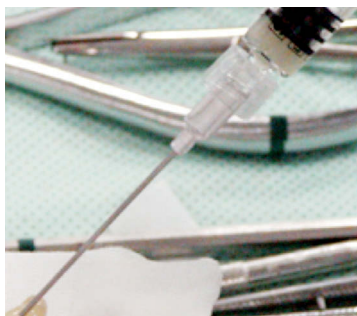
Three months of cryopreservation



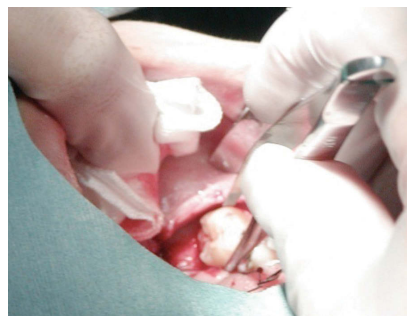
Thawing at 37°C



Perforation



Second molar transplantation



One year after transplantation

Do you believe that, in the future, human teeth will become organs eligible for donation, especially in countries that do not have access to modern technologies? Do you believe that it will be possible to “recreate teeth”? Is it possible to implement the technology of teeth bank in Brazil? (Matheus Melo Pithon)

Our storage system is strictly maintained to preserve and reimplant the teeth from and to the same patient. Several infectious diseases can exist in the oral cavity where they can be passed on in case transplantation is

carried out in a distinct receptor. This is a basic principle behind our teeth bank. With regard to your second question, we have already implemented our system of teeth bank at the Medical School of Taipei University, in Taiwan. For this reason, it is perfectly possible to implement the same system in Brazil, provided that some basic principles are met. I would like to request that everybody seek new innovations in favor of Dentistry and Orthodontics. Finally, I would like to express my sincere thanks to Dental Press Journal of Orthodontics, all the interviewers as well as readers.

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Dental and skeletal components of Class II open bite treatment with a modified Thurow appliance

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DOI: <http://dx.doi.org/10.1590/2176-9451.19.1.019-025.oar>

Introduction: Due to the lack of studies that distinguish between dentoalveolar and basal changes caused by the Thurow appliance, this clinical study, carried out by the School of Dentistry — State University of São Paulo/Araraquara, aimed at assessing the dental and skeletal changes induced by modified Thurow appliance.

Methods: The sample included an experimental group comprising 13 subjects aged between 7 and 10 years old, with Class II malocclusion and anterior open bite, and a control group comprising 22 subjects similar in age, sex and mandibular plane angle. Maxillary/mandibular, horizontal/vertical, dental/skeletal movements (ANS, PNS, U1, U6, Co, Go, Pog, L1, L6) were assessed, based on 14 landmarks, 8 angles (S-N-ANS, SNA, PPA, S-N-Pog, SNB, MPA, PP/MPA, ANB) and 3 linear measures (N-Me, ANS-Me, S-Go).

Results: Treatment caused significantly greater angle decrease between the palatal and the mandibular plane of the experimental group, primarily due to an increase in the palatal plane angle. ANB, SNA and S-N-ANS angles significantly decreased more in patients from the experimental group. PNS was superiorly remodeled. Lower face height (ANS-Me) decreased in the experimental group and increased in the control group.

Conclusions: The modified Thurow appliance controlled vertical and horizontal displacements of the maxilla, rotated the maxilla and improved open bite malocclusion, decreasing lower facial height.

Keywords: Angle Class II malocclusion. Open bite. Orthopedics.

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

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INTRODUCTION

Class II malocclusion can be due to skeletal or dental maxillary protrusion, mandibular retrusion or a combination of factors.^{1,2,3} While Class II malocclusion can be addressed in a number of different ways (i.e. dentoalveolar changes, orthopedic forces to inhibit maxillary growth or stimulate mandibular growth, or surgical repositioning of the mandible in non-growing patients), maxillary protrusion is usually treated with orthopedic forces produced by headgear appliances.^{3,4,5} Headgear appliances can be inserted into bands bonded onto the upper molars or into removable appliances. The issue of whether or not headgear therapy causes skeletal maxillary changes in humans remains controversial.⁶⁻⁹

When associated with hyperdivergence and anterior open bite, Class II malocclusions have proven to be a daunting challenge for orthodontists. The position of the tongue as well as thumb and finger sucking are perhaps the best known physical factors that cause open bite malocclusions.¹⁰ Hyperdivergent open bite subjects have anterior and posterior dentoalveolar heights that tend to be excessive, palatal plane angles that are flatter, as well as increased mandibular plane and gonial angles.¹¹ To treat such malocclusion in growing patients, it is necessary to limit maxillary displacement and intrude the molars in order to rotate the mandible upwards and forward.^{12,13}

The Thurow appliance was developed to apply distal and vertical forces while controlling molar rotation and tipping produced by forces directed through buccal molar tubes. The original appliance, which incorporates a high-pull headgear and a maxillary acrylic splint that serves as a bite block, has been shown to restrain maxillary growth, distally tip and displace the maxillary teeth, as well as restrain the eruption of posterior maxillary teeth.^{14,15} Because the splint precisely covers the entire maxillary dentition, higher force levels dissipating over a larger surface area can be used. The acrylic smooth surface disoccludes the teeth and effectively eliminates occlusal interferences during force application, which facilitates maxillary tooth movement and allows the mandible to grow unimpeded by the maxilla. The Thurow appliance is thought to be particularly well suited for Class II patients with maxillary prognathism, steep mandibular plane angles and open bites.¹⁶

It has been reported that the Thurow appliance can be used to decrease the ANB angle, inhibit maxillary horizontal growth, control vertical growth of the maxilla, maintain the mandibular plane angle, move the upper first molars distally, and improve lip relationships.^{12,13,16-19} However, these claims have been based on case reports which have not been compared to control groups. Existing case-control studies were not able to distinguish between dentoalveolar and basal changes produced by the appliance because mandibular and, especially, maxillary superimpositions were not performed.^{14,20,21}

The ability to distinguish between skeletal/dental contributions and correction is important not only to ensure that treatment objectives were met, but also to further improve therapies performed with the appliance. Clinically, understanding the effects of Thurow high-pull headgear is vital to understand Class II correction in growing hyperdivergent patients. The aim of this retrospective study was to assess dental and skeletal changes produced by a Thurow high-pull headgear appliance for hyperdivergent patients with open bite and Class II division 1 malocclusion, by means of cephalometric radiographs.

MATERIAL AND METHODS

Sample

Fifteen children participated in this retrospective clinical study as a treated group. Recruitment was conducted at the orthodontic clinic of the School of Dentistry — State University of São Paulo/Araraquara. During treatment, two patients moved away from the city.

The final treated group included 13 children (1 male and 12 female) with Class II division 1 malocclusion as well as open bite. The children aged between 7 and 10 years old and were treated for 12 months before growth spurt (Table 1). The maxillary splint high-pull headgear comprised an acrylic plate, a vestibular arch, an extraoral arch fixed to the acrylic, a palatal crib, and an expansion screw at the level of the second deciduous molars (Fig 1); and it was based on the appliance introduced by Thurow¹⁶ and modified by Santos-Pinto.¹⁸ The acrylic plate extended laterally and occlusally, covering the cusps and approximately one-third of the molars buccal surfaces. Should expansion be necessary, the screw was activated once a week (0.25 mm) for as long as it was needed. The outer bow of the extraoral

Table 1 - Pre-treatment and follow-up ages of the treated (Thurrow appliance) and untreated (control) groups.

	Group	Sample size	Mean $\pm$ SD	Prob.
Initial	Treated	13	8.85 $\pm$ 0.73	0.912
	Untreated	22	8.82 $\pm$ 0.73	
Final	Treated	13	9.84 $\pm$ 0.70	0.933
	Untreated	22	9.82 $\pm$ 0.73	

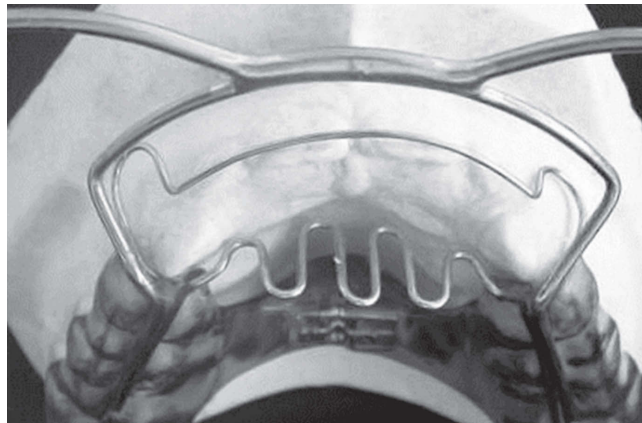


Figure 1 - Modified Thurrow appliance.

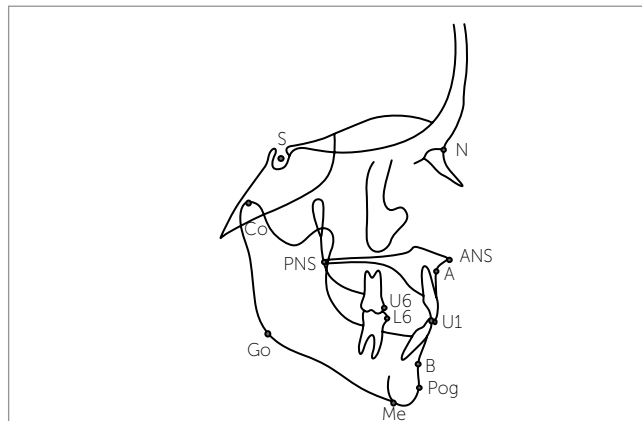


Figure 2 - Cephalometric landmarks digitized; (S) sella, (N) nasion, (PNS) posterior nasal spine, (ANS) anterior nasal spine, (A) A-point, (Co) condylion, (Go) gonion, (Me) menton, (Pog) pogonion, (B) B-point, (U6) maxillary mesial molar, (U1) maxillary incisor tip, (L6) mandibular mesial molar, (L1) mandibular incisor tip.

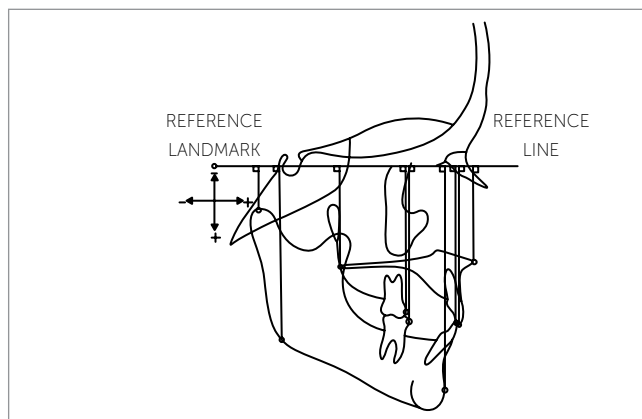


Figure 3 - Horizontal and vertical cephalometric landmarks position measured parallel and perpendicular to the reference line (SN = -7°).

arch was adjusted so that the line of force of the elastics slightly passed anteroposteriorly through the first and second deciduous molars and between the lower margin of the orbitale, and vertically through the apex of the first molar, which is slightly posterior to the maxilla center of resistance.^{22,23} The high-pull headgear delivered approximately 400 g of force on each side and was worn 14 hours a day. After correction was achieved, the patients wore the headgear for 8 to 10 hours during sleep. They were seen monthly so that the splint could be adjusted, if necessary.

The untreated control group included children who were followed longitudinally at the Human Growth Research Center, University of Montreal, Canada. They were from three different school districts in Montreal and represented various socioeconomic strata.²⁴ The control group sample comprised 22 patients (2 males and 20 females) with Class II division 1 who were at the same age, with the same sex and mandibular plane angle when compared to the treated sample.

Cephalometric methods

Lateral cephalograms were obtained at the beginning of the treatment (T_1) and at the follow-up appointment (T_2) in the treated group. In the control group, the lateral cephalograms were obtained after one year, at least fifteen days before or after the initial day. The cephalograms were taken with the head positioned according to the Frankfort horizontal plane, and the lateral cephalometric tracings were performed on acetate paper. The tracings were digitized and analyzed with Viewbox 3.1-Cephalometric Software (Dhal Software, Athens, Greece) by one investigator. The linear measurements were adjusted to eliminate magnification. The analyses described growth and treatment changes of fourteen skeletal landmarks (Fig 2).

The horizontal and vertical movements of the selected landmarks were described on the basis of a horizontal reference line (RL), which was oriented in T_1 based on the sella-nasion plane with -7 degrees. For example, the horizontal change in the position of pogonion was measured parallel to the RL (distance between the pogonion projection to a reference point fixed 100 mm behind the sella), while the vertical change was measured perpendicular to the RL (Fig 3).

In general, tooth movements were calculated based on tracings superimposed to the stable cranial base structures, as described by Björk and Skieller.²⁵ To determine the actual movement of incisors and molars, maxillary and mandibular superimpositions were also performed, as described by Björk and Skieller.^{25,26} After partial superimposition, tooth movements were subtracted from the overall tooth movements in order to estimate the movement of the skeletal bases. Horizontally, an anterior change was recorded as positive, whereas a posterior change was recorded as negative. Vertically, a superior change was recorded as negative, whereas an inferior change was recorded as positive (Fig 3).

Replicate analysis of 26 subjects showed small, but statistically significant systematic errors for the ANS horizontal (0.31 mm) and Go vertical (-0.21 mm). Random method errors ranged from 0.15 to 0.46 mm with PNS horizontal showing the largest random error.²⁷

Statistical methods

The measurements were transferred to SPSS software (version 15.0, SPSS, Chicago, USA) for evaluation. Based on Skewness and Kurtosis, the variables were normally distributed. T-tests were used to compare the groups. A probability level of 0.05 was used to determine statistical significance.

RESULTS

T-tests showed significant ($P < 0.05$) differences between groups prior to treatment of five out of the 11 traditional variables measured (Table 2). In comparison to the control group, the treated group initially

had greater ANB angles, smaller palatal plane angles and greater anterior and posterior facial heights. Analysis of covariance demonstrated that none of the traditional pretreatment variables were related to post-treatment changes.

Regardless of pretreatment measures, the treatment yielded significant differences. The palatal plane angle increased in the treated group and remained unchanged in the control. This difference, along with the greater, although not statistically significant decrease in the MPA, resulted in a significantly greater decrease in the PP/MPA of the treated group. The ANB angle significantly decreased more in treated patients than in the control group, primarily due to a significant treatment decrease in the SNA angle. While lower face height increased significantly in the control, it significantly decreased in the treated group.

In comparison to the treated group, which showed no statistically significant horizontal displacement, the maxilla and maxillary teeth of the control group were anteriorly displaced approximately 0.7 mm over the observation period (Table 4). Although the treated group showed anterior displacement of the mandible, the changes were not statistically significant. All mandibular landmarks of the control group showed significant anterior displacement, except for the condylion. None of the differences regarding horizontal displacement between groups were statistically significant.

Based on the maxillary superimpositions, the treated group demonstrated no statistically significant difference with regard to horizontal remodeling or tooth migration; the control group showed

Table 2 - Comparison of pretreatment values between treated and untreated groups.

Variable		Treated		Untreated		Prob. (difference)
		Mean $\pm$ SD		Mean $\pm$ SD		
S-N-ANS	Deg	87.45	5.88	86.38	2.62	0.548
SNA	Deg	82.37	5.93	81.27	3.19	0.550
PPA	Deg	3.99	3.40	6.91	2.79	0.016
SNPog	Deg	77.25	5.14	77.28	3.02	0.981
SNB	Deg	77.21	5.45	77.50	3.10	0.862
MPA	Deg	35.97	5.30	36.27	3.60	0.855
PP/MPA	Deg	31.96	4.62	29.19	3.41	0.076
ANB	Deg	5.16	1.90	3.72	2.00	0.046
N-Me	mm	96.58	4.58	92.03	4.02	0.007
ANS-Me	mm	58.23	3.99	53.02	2.66	0.001
S-Go	mm	60.82	5.25	57.27	3.90	0.047

Table 3 - Comparison of changes between treated and untreated groups.

Variable		Treated		Untreated		Prob. (difference)
		Mean $\pm$ SD		Mean $\pm$ SD		
S-N-ANS	Deg	-2.75	1.20	0.08	1.45	<0.001
SNA	Deg	-0.94	0.80	0.03	1.15	0.007
PPA	Deg	2.14	1.59	0.07	0.85	<0.001
S-N-Pog	Deg	0.27	1.12	0.33	0.66	0.871
SNB	Deg	0.16	0.95	0.22	0.59	0.846
MPA	Deg	-0.61	1.63	-0.17	0.99	0.392
PP/MPA	Deg	-2.73	1.92	-0.23	1.12	0.001
A-N-B	Deg	-1.10	0.88	-0.12	1.15	0.010
N-Me	mm	1.64	1.55	2.36	1.52	0.198
ANS-Me	mm	-0.92	1.44	1.14	1.26	<0.001
S-Go	mm	1.68	1.68	1.64	0.89	0.938

anterior and posterior remodeling of ANS and PNS, respectively, and mesial drift of the incisors molars. Except for the gonion of the control group, which drifted posteriorly, and for the lower molar of the treated group, which moved mesially, none of the mandibular measures showed statistically significant horizontal changes. While several of the group comparisons were at a significant level, none of the differences were statistically significant.

Both groups showed statistically significant inferior displacement, with no significant differences between groups (Table 5). The maxilla was inferiorly displaced for approximately 1 mm. The posterior and anterior aspects of the mandible were inferiorly displaced for approximately 2.9 to 3.4 mm and 1.5 to 2.3 mm, respectively. While ANS showed no significant remodeling changes, PNS showed slight superior drift in the treated group and inferior drift in the control group, with statistically significant differences.

The maxillary molars of the treated group showed no vertical changes, whereas the control molars erupted approximately 0.8 mm. There was little or no group difference in mandibular remodeling and tooth movements. Condylion showed the greatest growth (2.6 to 2.8 mm), gonion drifted superiorly, the incisors erupted 0.8 to 1.2 mm and the mandibular molars erupted 0.8 to 0.9 mm.

DISCUSSION

The modified Thurow appliance clearly restricted the forward growth of the maxilla. The treated subjects showed a decrease of 2.8° and 0.9° in S-N-ANS and SNA, respectively. The angles decreased in the treated group because the maxilla maintained its anteroposterior position while the nasion continued to drift anteriorly. The control group showed little or no change in SNA or S-N-ANS because the maxilla moved forward along with the nasion. This distinction is important

Table 4 - Horizontal skeletal and dental changes in treated and untreated patients (positive value = forward direction; negative value = backward direction).

Horizontal values			
Displacement			
Variable	Treated Mean ± SD	Untreated Mean ± SD	Prob. (difference)
ANS	0.01 ± 0.83	0.72 ± 1.16	0.060
PNS	0.02 ± 0.84	0.74 ± 1.21	0.068
U1	0.15 ± 1.62	0.71 ± 1.56	0.315
U6	0.12 ± 1.35	0.72 ± 1.41	0.229
Co	-0.42 ± 2.42	0.15 ± 1.73	0.418
Go	0.63 ± 2.12	0.93 ± 1.37	0.618
Pog	1.32 ± 2.66	1.44 ± 1.84	0.878
L1	0.59 ± 2.17	0.86 ± 1.38	0.654
L6	0.55 ± 2.11	0.86 ± 1.37	0.592
Remodeling / tooth movement			
Variable	Treated Mean ± SD	Untreated Mean ± SD	Prob. (difference)
ANS	0.35 ± 1.18	0.78 ± 1.36	0.428
PNS	-1.14 ± 1.93	-0.81 ± 1.14	0.699
U1	-0.02 ± 1.53	0.80 ± 1.14	0.091
U6	0.33 ± 1.15	0.56 ± 1.16	0.625
Co	0.25 ± 2.54	-0.54 ± 1.71	0.159
Go	-0.55 ± 1.64	-1.45 ± 1.31	0.053
Pog	0.02 ± 0.13	-0.07 ± 0.25	0.271
L1	0.74 ± 1.44	0.34 ± 0.94	0.203
L6	0.98 ± 1.28	0.36 ± 0.96	0.121

Bold = significant change between initial and final radiographs.

Table 5 - Vertical skeletal and dental changes in treated and untreated patients (positive value = inferior direction; negative value = superior direction).

Vertical values			
Displacement			
Variable	Treated Mean ± SD	Untreated Mean ± SD	Prob. (difference)
ANS	0.80 ± 1.47	0.98 ± 1.54	0.740
PNS	1.02 ± 1.08	1.00 ± 0.69	0.964
U1	0.83 ± 1.42	1.00 ± 1.48	0.749
U6	0.96 ± 0.88	0.96 ± 0.89	0.995
Co	2.94 ± 2.30	3.53 ± 2.13	0.448
Go	2.86 ± 2.25	3.40 ± 1.95	0.466
Pog	1.51 ± 1.82	2.31 ± 1.28	0.180
L1	1.37 ± 1.97	2.23 ± 1.36	0.181
L6	1.89 ± 1.70	2.59 ± 1.22	0.168
Remodeling / eruption			
Variable	Treated Mean ± SD	Untreated Mean ± SD	Prob. (difference)
ANS	0.22 ± 0.44	0.37 ± 1.75	0.775
PNS	-0.50 ± 0.57	0.21 ± 0.43	0.001
U1	1.03 ± 0.91	0.93 ± 1.45	0.243
U6	0.33 ± 1.15	0.82 ± 0.95	0.073
Co	-2.63 ± 2.69	-2.82 ± 1.75	0.371
Go	-1.25 ± 1.69	-1.74 ± 1.85	0.489
Pog	0.11 ± 0.14	0.04 ± 0.71	0.699
L1	-1.24 ± 1.49	-0.82 ± 1.14	0.319
L6	-0.94 ± 0.86	-0.84 ± 0.77	0.448

Bold = significant change between initial and final radiographs.

because previous studies have reported, based solely on decreases in SNA or S-N-ANS, that headgears used to correct Class II malocclusions are generally effective in posteriorly redirecting maxillary growth.^{14,16,20,21,28-31}

Most studies have not assessed the actual antero-posterior movement of the maxilla. Baumrind et al,⁸ who used the biologically defined “best fit” of palatal structures, showed small, but definite posterior movement of ANS. In the present study, ANS was not displaced posteriorly, perhaps due to the more superiorly oriented forces produced by the high-pull headgear.

The modified Thurow appliance produced 2.1° posteriorly, or a backward rotation of the palatal plane. In contrast with the control group, the treated group showed no statistically significant changes of the palatal plane angle, as expected for untreated subjects over a similar time period.³³⁻³⁶ Other studies evaluating the effects of high-pull forces have all shown backward rotation of the palatal plane.^{14,20,30,37,38}

In some situations, the orthodontist wants to prevent maxillary rotation, in which case the high-pull forces should be directed through the maxilla center of resistance.

In this study, the headgear forces were purposely directed behind the dental and maxillary centers of resistance in order to help correcting the open bite. Rotation of the palatal plane also explains the decrease observed in the lower anterior face height of the treated group.^{20,31} Lower anterior face height of the control group increased, as expected during growth of untreated subjects.^{33,34,36}

The modified Thurow appliance used in the present study had no real treatment effects on the antero-posterior mandibular position. The S-N-Pog and SNB angles did not significantly change in either treated or control group. Previous studies also show no changes in the anteroposterior position of the mandible.^{14,20,21,32,39}

Lahaye et al,⁴⁰ who evaluated methods commonly used to correct Class II skeletal malocclusions, including headgears and Herbst appliances, found no appreciable significant improvements in anteroposterior chin position. The authors stated that skeletal Class II correction in growing adolescents results primarily from maxillary growth restriction or inhibition.

The mandibular plane angle did not show statistically significant differences between groups either. Both groups showed forward rotation during the observation period. Most previous studies have shown that the mandibular plane angle changed or was maintained during treatment.^{14,20,21,32,41} Except for Bhatia and Leighton,³⁶ who reported a slight increase for males and stable relations for females, previous longitudinal studies of untreated children have also shown decreases in the MPA between 10-15 years, ranging from 0.8 to 3.5°.^{33,34,35}

CONCLUSION

1. The modified Thurow appliance held the maxilla and caused a slight backward rotation of the palatal plane.
2. The maxillary molars of the treated group showed neither horizontal nor vertical changes. The upper incisors were retroclined, but no significant change was observed over time.
3. Except for the lower molars, which moved mesially in the treated group, no treatment effect was observed in the mandible.
4. Lower facial height decreased in the treated group.

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An assessment of the maxilla after rapid maxillary expansion using cone beam computed tomography in growing children

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Introduction: With the advent of cone beam computed tomography (CBCT), it is now possible to quantitatively evaluate the effects of rapid maxillary expansion (RME) on the entire maxillary complex in growing patients.

Objective: The purpose of this study is to use three-dimensional images to evaluate the displacement that occurs at the circummaxillary sutures (frontonasal, zygomaticomaxillary, intermaxillary, midpalatal, and transpalatal sutures) following rapid maxillary expansion in growing children.

Methods: The CBCT scans of 25 consecutively treated RME patients (10 male, 15 female) with mean age of 12.3 ± 2.6 years, were examined before expansion and immediately following the last activation of the expansion appliance.

Results: Statistically significant ($P < 0.05$) amounts of separation were found for the displacement of the bones of the frontonasal suture, the intermaxillary suture, the zygomaticomaxillary sutures, and the midpalatal suture. The change in angulation of the maxillary first molars due to RME was also statistically significant. There was no statistically significant displacement of the transpalatal suture.

Conclusions: Rapid maxillary expansion results in significant displacement of the bones of circummaxillary sutures in growing children.

Keywords: Palatal expansion technique. Orthodontics. Cone beam computed tomography. Cranial sutures.

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

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

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INTRODUCTION

Rapid maxillary expansion (RME) is the most common orthopedic procedure used to correct a maxilla with transverse discrepancy. Heavy orthopedic forces are used to separate the two halves of the maxilla at the midpalatal suture.¹ Indications for RME include the need to correct posterior crossbite and to increase arch perimeter in patients with a tooth-size arch-length deficiency to address crowding.^{2,3}

Along with the opening of the midpalatal suture,^{4,5} RME has an effect on the entire maxillary complex.⁶⁻⁹ According to Starnbach et al,¹⁰ palatal expansion does not only separate the midpalatal suture, but the circumzygomatic and circummaxillary sutural systems as well. Specifically, the nasal, the zygomaticomaxillary, and the zygomaticotemporal are some of the sutures affected by RME. Studies employing dry skulls,⁷ rhesus monkeys¹¹⁻¹⁴ and finite element models (FEM)^{15,16,17} have proved these sutures to be affected, but the descriptions tend to be qualitative in nature, except for the stress levels calculated by the FEM studies.

While there are significant contributions from all of these past studies, there are weaknesses associated with each type of study mentioned above. Studies on dry skulls lack the soft tissues that can hamper the effects of RME, particularly the connective tissue that forms the suture between bones. Rhesus monkeys have a significantly different maxillary anatomy in comparison to humans. The biggest problem FEM faces is the fact that the computer program used for the study is only as good as the model upon which it is based. FEM studies that examined RME were based upon one dry human skull each. Additionally, FEM studies do not demonstrate longitudinal effects, only a particular instant in time.

Many studies^{5,8,18-29} have attempted to quantify the changes that occur in the maxillary complex as a result of RME. Several studies have extensively reviewed the changes occurring at the midpalatal suture, the dentoalveolar structures, and the nasal cavities.^{9,25,28,30-33} However, the limitations of clinical examinations and two-dimensional radiography inhibit the analysis of what is occurring at the sutural levels in orthodontic patients. The introduction of cone beam computed tomography (CBCT) in Orthodontics^{34,35} now permits the examination of the craniofacial complex in living, growing subjects.

The purpose of this study is to use three-dimensional images to evaluate the changes that occur at the

circummaxillary sutures, including the frontonasal, zygomaticomaxillary, intermaxillary, midpalatal, and transpalatal ones, following rapid maxillary expansion in growing children. In addition, the relationship between the midpalatal suture and the other sutures are also analyzed.

MATERIAL AND METHODS

Patient selection

This investigation is a retrospective study approved by the Saint Louis University Institutional Review Board (#15727). The records of 25 consecutively treated patients (10 male, 15 female) were chosen from the records of private practice based on the following selection criteria:

Inclusion criteria

1. Diagnosis included a finding of skeletal transverse discrepancy, while treatment plan included the use of a rapid maxillary expansion appliance.
2. Complete set of CBCT images including one prior to appliance delivery and one taken immediately after the active expansion phase of treatment.

Exclusion criteria

1. Patients with craniofacial anomalies, including cleft lip and palate.
2. Patients with orthodontic appliances present prior to the start of treatment with rapid maxillary expansion.

Patients' mean age at the time of the first imaging appointment in this study was 12.3 ± 2.6 (8.3 to 17.8 years). The second CBCT image was taken on an average of 22.8 ± 5 days after the first image (14 to 37 days).

Each patient was treated with a tooth-borne rapid maxillary expander (Hyrax). The expansion appliance consisted of a 7-millimeter Dentaurem expansion screw (Dentaurem, Ispringen, Germany) with 0.051-inch diameter stainless steel arms welded to orthodontic bands on the maxillary first molars, and a 0.051-inch diameter supporting wire placed palatal to the dentition and bands so as to increase the rigidity of the appliance and extend the force of the expander to the canines as well as first and second premolars, if they were present (Fig 3).

The expander was activated two-quarter turns of the expansion screw (0.2 mm each turn) at the time of delivery, followed by a one-quarter turn twice a day. Activation of the screw continued until the transverse discrepancy was overcorrected to the point in which the palatal cusps of the maxillary molars were in edge-to-edge contact with the buccal cusps of the opposing mandibular teeth.

Imaging

Cone beam computed tomography scans were taken using the Classic i-CAT® (Imaging Sciences International, Inc., Hatfield, USA) cone beam CT scanner. All scans were taken by the same technician using either the 16 x 13 or the 16 x 22 centimeter field of view with a voxel size of 0.4 millimeters. Patients were positioned in a vertical seat with their head stabilized in the headrest to prevent any unwanted movement during the 20-second scan, teeth together in centric occlusion, and the Frankfort Horizontal plane parallel to the floor, as determined by the external auditory meatus and soft-tissue orbitale.

Each patient was scanned at two different time points: T_0 and T_1 . The first image (T_0) was obtained prior to the delivery of the expander and represented the subject's baseline condition prior to expansion. The second time point (T_1) was taken at the appointment immediately following the last activation of the expansion appliance.

The analysis measured changes of the alveolar bone and maxillary sutures following rapid maxillary expansion with consistent landmark identification using the Dolphin 3-D software (Dolphin Imaging & Management Solutions, Chatsworth, USA).

Each scan had a number randomly assigned and loaded into the three-dimensional software so that each scan was analyzed without the operator identifying the patient. First, each scan was oriented by locating the midpoint between both foramina spinosum (ELSA), and assigning to it $x = 0$, $y = 0$, and $z = 0$ coordinates (Fig 4). The following points were then located: 1) the superior-lateral border of the external auditory meatus (SLEAM) on both right and left sides, and 2) the mid-dorsum of the foramen magnum (MDFM). An axial-horizontal plane (x-y plane) was determined by using the right and left SLEAM points and ELSA. A sagittal-vertical plane (z-y plane) was determined perpendicular to the x-y plane and passing through points ELSA and MDFM. These points have shown a high intra-reliability when located with 3D images, which makes the x-y and z-y planes formed by these points an adequate way to standardize the orientation of 3D images.

Landmark location

Two-dimensional axial images were created perpendicular to the coronal plane and used to measure the amount of midpalatal and transpalatal suture separation on the external surface of each suture.

The midpalatal suture was measured adjacent to four locations: the first molar, the contact area between the first and second premolars, the canine, and the most anterior point of the maxillary dental arch.

The central groove of each first molar was identified by locating the crown of the molar on an axial image and marking the central groove. An axial section through the hard palate was then created, and the mesial edge of the midpalatal suture was marked

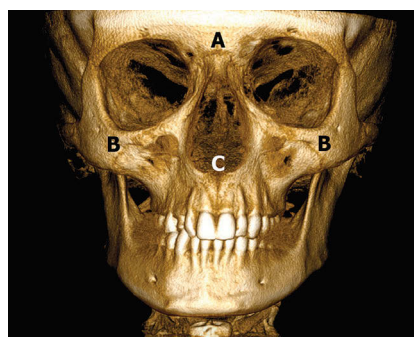


Figure 1 - Frontal skull showing evaluated areas. **A)** Frontonasal suture; **B)** Zygomaticomaxillary suture; **C)** Intermaxillary suture (ANS).

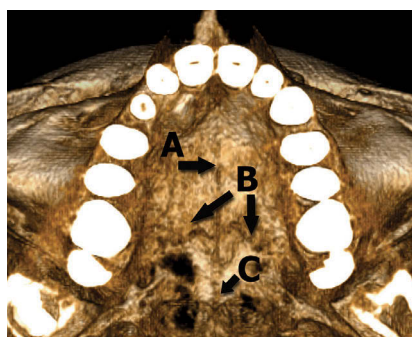


Figure 2 - Axial view of a skull showing evaluated areas. **A)** Midpalatal suture; **B)** Transpalatal suture; **C)** PNS.

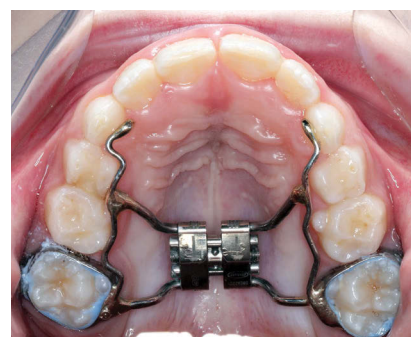


Figure 3 - Model of palatal expander.

on both right and left sides. The same procedure was followed for the other areas of the midpalatal suture, as described above (Fig 5). To verify if the external surface of the suture was being marked, coronal slices were viewed for the places where the suture edges were marked and corrected if necessary.

The transpalatal suture was measured at five areas along the suture. The first area identified was in the midline, established by the junction of the midpalatal and transpalatal sutures. The proximal and distal edges of the transpalatal suture were marked at the midline, as well as at 6, 12, and 18 millimeters to the left (Fig 6). The millimetric grid on the axial image was used to determine the landmarks to the left of the midline. To verify if the external surface of the suture was being marked, coronal slices were viewed for the places where the suture edges were marked and corrected if necessary.

The displacement of the frontonasal suture was determined by locating and marking the superior and inferior edges of the frontonasal suture on the external surface in the midline on a sagittal section (Fig 7).

Axial sections were used in the appropriate locations to locate and measure the mesial edges of the intermaxillary suture at ANS (Fig 8) as well as the proximal and distal edges of the zygomaticomaxillary sutures which were located and marked on both inferior (Fig 9) and superior (Fig 10) borders of the zygomaticomaxillary suture on both right and left sides.

To determine the amount of appliance expansion, the outer edges of an unactivated 7-mm Dentaureum expansion screw (Dentaureum, Ispringen, Germany) were measured with digital calipers. In the post-expansion scans, the outer edges of the expansion screw were marked in the coronal slice at the maxillary first molars (Fig 11).

The A point and the posterior nasal spine (PNS) were identified on a sagittal section (Fig 12).

To establish the amount of maxillary first molar angulation, the long axis of each first molar was determined by identifying the center of the pulp chamber on axial slices at several levels. Then, the angle of the each molar was calculated to the occlusal plane (Fig 13).

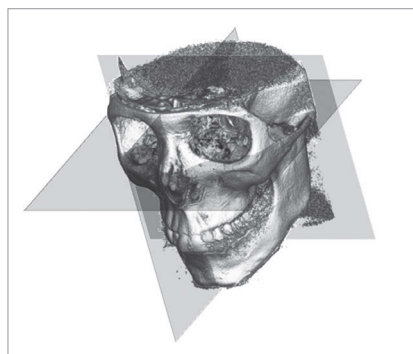


Figure 4 - CBCT image after orientation.

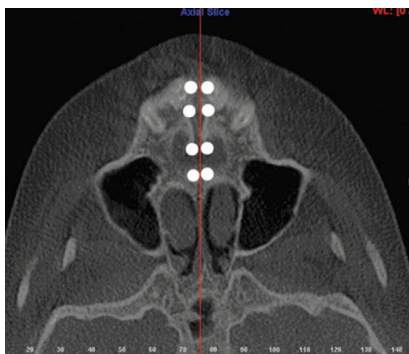


Figure 5 - Axial slice through the palate showing the midpalatal suture.

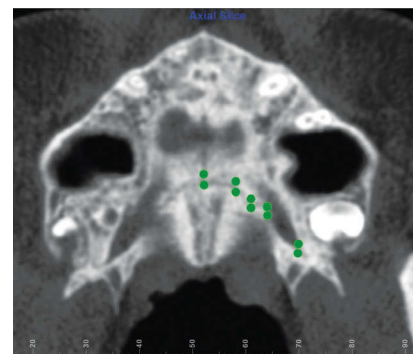


Figure 6 - Axial slice through the palate showing the transpalatal suture.



Figure 7 - Sagittal slice through the midline, with the frontonasal suture marked.

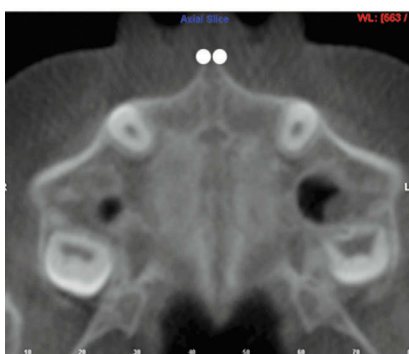


Figure 8 - Axial slice through the hard palate, with the intermaxillary suture marked at ANS on the right and left sides.

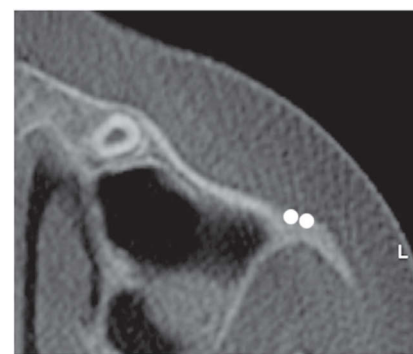


Figure 9 - Axial slice showing the left inferior border zygomaticomaxillary suture.



Figure 10 - Axial slice showing the left superior border of zygomaticomaxillary suture.



Figure 11 - Post-expansion coronal slice at the central groove of the maxillary first molar, with the expansion screw in the center.

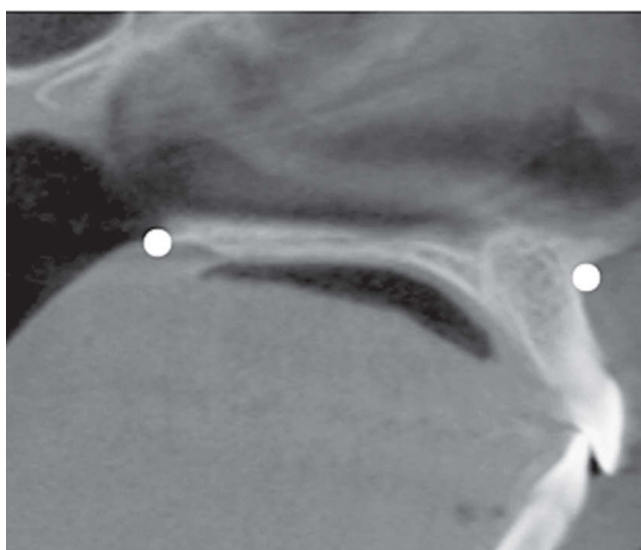


Figure 12 - A point (right) and PNS (left) on a sagittal slice through the midline.

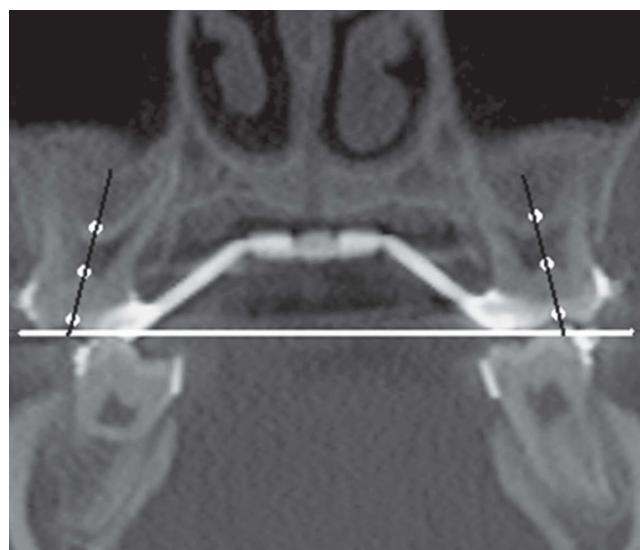


Figure 13 - Angulation of the maxillary first molars measured at the occlusal plane.

For each landmark described above, the x, y, and z coordinates were recorded at both T_0 and T_1 for each patient. The value in millimeters for each coordinate was entered into an Excel software spreadsheet (Microsoft, Redmond, Washington, USA). To calculate the width of each suture, the distance between the two edges was calculated for each coordinate. To calculate the amount of expansion, the difference between the right and left sides of the expansion jackcrew was computed for each coordinate. Analytical geometry was used to convert each set of coordinates into a single value. The resulting value was the width of a suture

at a particular location or the amount of appliance expansion. These calculations were done for all of the x, y, and z coordinates for both time intervals.

Statistics

All statistics were calculated using the SPSS 14.0 Statistical Software (SPSS Inc., Chicago, Illinois, USA) on a personal computer. Descriptive statistics were calculated for all suture width measurements and for appliance expansion as well as maxillary first molar angulation and change in position of A point and PNS.

To calculate intra-examiner reliability, 25% of the CBCT scans were re-measured to test the reliability of landmark identification with an intraclass correlation coefficient. Reliability of scan orientation was also calculated using the intraclass correlation coefficient by re-orienting 25% of the CBCT scans and using the cranial base landmarks basion and anterior clinoid process of sella turcica for comparison.

Non-parametric statistics were used due to the small sample size.³⁷ Changes in measurements between pre and post expansion for each of the sutures were analyzed using single-tailed Wilcoxon signed rank tests with a level of significance set at $P < 0.05$. Kendall's Tau-b correlations with a significance level set at $P < 0.05$ were calculated to assess the relationships between the various sutures and the amount of expansion.

RESULTS

The intraclass correlation coefficient proved the measurements and orientation to be very reliable. Cronbach's Alpha measurement of 0.947 showed that there was no significant difference between the original measurements made and the repeated measurements performed on a sample that was randomly selected and represented in 25% of the sample. Likewise, Cronbach's Alpha measurement of 0.967 showed that there was no significant difference between the original orientation made and the repeated orientation performed on a sample that was randomly selected and represented in 25% of the sample.

Descriptive statistics for the changes in suture width measurements between T_0 and T_1 as well as the amount of appliance expansion are listed in Table 1.

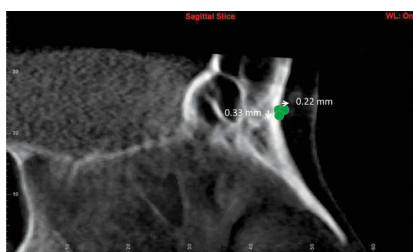


Figure 14 - Frontonasal suture movements in Y and Z planes (sagittal slice).



Figure 15 - Intermaxillary suture movement at ANS in X plane (axial slice).

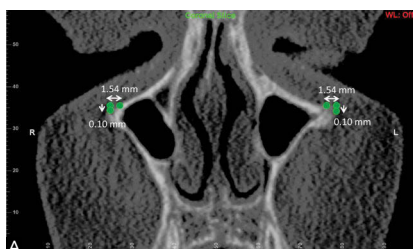


Figure 16 - Superior zygomaticomaxillary suture movements in **A)** X and Y planes (coronal slice) and **B)** X and Z planes (axial slice).

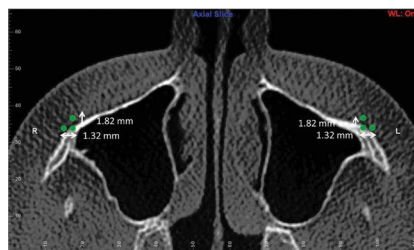
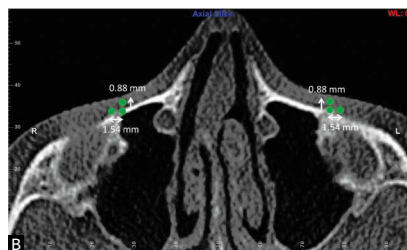


Figure 17 - Inferior zygomaticomaxillary suture movements in X and Z planes (axial slice).

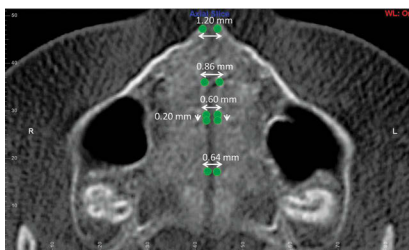


Figure 18 - Midpalatal suture movements in X and Z planes (axial slice).



Figure 19 - Movements in Y and Z planes (sagittal slice) of A point (right) and PNS (left).

Table 1 - Descriptive statistics of sutural displacement (T_1-T_0).

Measurement (mm)	n	Minimum Value	Maximum Value	Mean $\pm$ SD
Appliance expansion	25	1.8	6.8	4.2 $\pm$ 1.1*
Frontonasal suture displacement	25	0.1	1.8	0.6 $\pm$ 0.4*
Intermaxillary suture displacement	25	0.0	3.1	1.9 $\pm$ 0.8*
Right superior zygomaticomaxillary suture displacement	25	0.3	3.6	1.2 $\pm$ 0.9*
Left superior zygomaticomaxillary suture displacement	25	0.0	1.7	0.6 $\pm$ 0.4*
Right inferior zygomaticomaxillary suture displacement	25	0.4	4.2	1.1 $\pm$ 0.9*
Left inferior zygomaticomaxillary suture displacement	25	0.4	3.7	1.2 $\pm$ 0.8*
Midpalatal suture displacement at maxillary first molar	25	0.1	2.0	0.9 $\pm$ 0.5*
Midpalatal suture displacement at contact between maxillary first and second premolar	25	0.1	2.4	0.8 $\pm$ 0.6*
Midpalatal suture displacement at maxillary canine	25	0.2	2.8	1.1 $\pm$ 0.7*
Midpalatal suture displacement at the most anterior point of the maxillary dental arch	25	0.5	3.0	1.5 $\pm$ 0.6*
Transpalatal suture displacement at the palatal midline	25	0.3	3.3	1.2 $\pm$ 0.8
Transpalatal suture displacement 6 mm to left to palatal midline	25	0.1	1.5	0.7 $\pm$ 0.4
Transpalatal suture displacement 12 mm to left to palatal midline	25	0.1	2.3	0.7 $\pm$ 0.5
Transpalatal suture displacement 18 mm to left to palatal midline	25	0.0	2.8	0.6 $\pm$ 0.6

*Indicates displacement is statistically significant ($p < 0.05$)

Statistically significant differences were found for the sutural displacement of the frontonasal suture ($z = -3.714$, $P < 0.001$), the right superior zygomaticomaxillary suture ($z = -3.951$, $P < 0.001$), the right inferior zygomaticomaxillary suture ($z = -2.677$, $P < 0.007$), the left superior zygomaticomaxillary suture ($z = -3.415$, $P < 0.001$), the left inferior zygomaticomaxillary suture ($z = -3.633$, $P < 0.001$), the intermaxillary suture, as measured at ANS ($z = -4.200$, $P < 0.001$), and all landmarks along the midpalatal suture ($P < 0.001$). There was no statistically significant displacement regarding the transpalatal suture at any of the measured landmarks. A point had a statistically significant movement after RME, however, PNS did not, even though it had 1.03 millimeters of movement downward.

When the individual x, y, and z coordinates were evaluated, the movement of the edges of the sutures was found to be significant in some directions. The results are listed in Table 2. Figures 14 to 18 demonstrate the significant movements for each assessed suture. Figure 19 demonstrates the movement of A point and PNS.

Kendall's correlations showed weak relationships between the midpalatal suture at the first molar and the frontonasal suture ($t = 0.261$, $P < 0.036$) as well as the superior border of the zygomaticomaxillary suture and the midpalatal suture at: the most anterior aspect of the dental

arch ($t = 0.418$, $P < 0.002$), the contact between first and second premolars ($t = 0.322$, $P < 0.012$), and at the first molar ($t = 0.364$, $P < 0.006$). There was also a weak relationship between the inferior border of the zygomaticomaxillary suture and the midpalatal suture at the most anterior aspect of the dental arch ($t = 0.261$, $P < 0.034$).

The difference in angulation of the maxillary first molars to the occlusal plane was statistically significant (right: $z = -3.135$, $P < 0.001$, left: $z = -3.586$, $P < 0.001$) before and after RME. Prior to RME, the right first molar had an average angulation of 87.3° while the left first molar had an average angulation of 84.4° . After RME, the right first molars crown tipped buccally with an average resulting angle of 82.3° and the left first molars crown also tipped buccally with an average resulting angle of 78.8° . Using geometry to calculate the intramolar angle, the pre-RME angle between right and left maxillary first molars was 12.3° and after RME it increased to 22.7° .

DISCUSSION

To date, there are a number of methods for studying the effects of rapid maxillary expansion. However, the literature does not reach a consensus regarding which approach is superior. In addition, the use of non-distorted three-dimensional imaging is a relatively new

Table 2 – Significant movement of individual coordinates.

		X	Y	Z
Frontonasal suture	z value		-3.115	-2.642
	sig (one-tailed)	NS	0.001	0.004
	movement (mm)		-0.33	0.22
Intermaxillary suture (ANS)	z value	-4.203		
	sig (one-tailed)	0.001	NS	NS
	movement (mm)	1.82		
Superior border of zygomaticomaxillary suture	z value	-5.505	-2.894	-6.037
	sig (one-tailed)	0.001	0.002	0.001
	movement (mm)	1.54	-0.1	0.88
Inferior border of zygomaticomaxillary suture	z value	-5.475		-5.761
	sig (one-tailed)	0.001	NS	0.001
	movement (mm)	1.32		1.82
Midpalatal suture at maxillary first molar	z value	-3.46	-2.236	
	sig (one-tailed)	0.001	0.01	NS
	movement (mm)	0.64	-0.02	
Midpalatal suture at contact of maxillary first and second premolar	z value	-3.353		-2.432
	sig (one-tailed)	0.001	NS	0.008
	movement (mm)	0.6		-0.12
Midpalatal suture at maxillary canine	z value	-3.742	-1.732	
	sig (one-tailed)	0.001	0.04	NS
	movement (mm)	0.86	-0.01	
Midpalatal suture at the most anterior point of the dental arch	z value	-4.186		
	sig (one-tailed)	0.001	NS	NS
	movement (mm)	1.2		
A point	z value			-1.672
	sig (one-tailed)	NS	NS	0.05
	movement (mm)		-2.99	-1.39

technique being in Orthodontics used to quantify the skeletal and dental effects of rapid maxillary expansion.

Although there are many studies^{5,8,18–28} regarding rapid maxillary expansion, very few have used cone beam computed tomography technology.²⁵

The sample size of 25 was substantially larger than the one used in many other three-dimensional studies. This gave more power to the statistical analyses to reveal significant differences when they existed. This sample was also unique in the fact that the CBCT images were taken relatively close together, with the second image occurring shortly after the active expansion of the appliance was finished. This eliminates most of the remodeling and growth, as well as relapse that appears in other studies.

The midpalatal suture exhibited significant displacement due to RME, with the amount of displacement being greater in the anterior than in the posterior. As this result is consistent with previous studies,^{5,8,18–28}

the displacement of other sutures was of more interest for this study. Many studies have concluded that the palatal shelves tip down as well as move apart transversely during RME. In this study, only the transverse movement was shown to be significant along the midpalatal sutures edges. There was significant downward movement at the contact of the first and second premolars, but the amount was only a fraction of a millimeter.

In studies carried out with rhesus monkeys, Starnbach¹⁰ noted that during RME, there was increased cellular activity at the zygomaticomaxillary suture, indicating bone formation at that suture. In contrast, another study conducted by Gardner¹³ on a different group of rhesus monkeys did not demonstrate any activity at that suture during RME. FEM studies^{15,16,17} have suggested that the zygomaticomaxillary sutures are places of compressive forces during palatal expansion. The results of this study show an average of 1.2 mm of sutural displacement at both the superior

and inferior borders of these sutures, which is more consistent with the results that Starnbach¹⁰ showed histologically. Previous RME studies carried out with children did not assess zygomaticomaxillary sutures, most likely due to the difficulty in identifying the suture on posteroanterior or lateral cephalograms. When the individual planes are evaluated, the superior borders of the zygomaticomaxillary suture move transversely by an average of 1.54 mm, but the borders move slightly downward (0.1 mm) and forward (0.88 mm) as well. The inferior borders of the of the zygomaticomaxillary suture also move transversely by an average of 1.32 mm, and forward by an average of 1.82 mm. These findings are consistent with the accepted fact that the entire maxilla moves down and forward with RME.

The frontonasal suture proved to have a significant amount of displacement, with an average displacement of only 0.6 mm. The movement of the borders of this suture was also in a down and forward direction, as expected. However, other studies have suggested that the greatest response to maxillary expansion outside of the oral cavity is found at this suture.¹²

The intermaxillary suture is usually included as an extension of the midpalatal suture, since it appears to be continuous with that suture. The displacement of the intermaxillary suture was measured at its most apical landmark, the ANS. It is interesting to note that this is the only suture with significant displacement which had a significant correlation with the amount of expansion of the appliance. The only significant movement was in a transverse direction at ANS.

Assessment of A point showed a significant displacement backward. A point also had an average displacement of nearly 3 mm downward, but this was not statistically significant. Additionally, PNS had an average downward displacement of about 1 mm, which was not statistically significant. Studies have shown contradictory results regarding the tipping of the palatal plane, with some studies showing that the posterior tipping was greater than that at the anterior aspect, while other studies show no significant tipping. Even with some relatively large downward measurements, this study proved that the tipping of the palatal plane is not significant with RME.

The lack of significant change in the transpalatal suture appears to confirm a prior study⁷ carried out with dried skulls and human patients in which the palatine bones do not separate from the maxillary bones under the forces of palatal expansion. Timms⁷ proposed it was the connection to the sphenoid bone that prevented the sutural displacement and the pterygoid processes from simply bending in response to the expansion forces. While the separation of the transpalatal suture was not statistically significant, there was some separation in some patients. A larger sample size may be able to refute or confirm these results.

Only the external surfaces of sutures were examined during this study. The changes that occurred during RME were recorded in all three planes of space. The element of time was disregarded, since there was, on average, only about 3 weeks between T_0 and T_1 . While the subjects were all growing children, the amount of growth that occurs over 3 weeks is negligible.

The RME appliance for this study was directly attached to the maxillary first molars, and one would expect that the molars would tip buccally as a result of the expansion forces. While there were individual variations, the molars did as predicted with about a 10 degree increase in the intermolar angle as a result of RME.

This study has established the fact that circummaxillary sutures are affected by RME in growing children, and that the movements of facial bones can be reliably quantified in three planes of space using CBCT. The overall forward and downward movement of the maxilla can be seen, as well as the transverse changes. Individual assessment of the changes occurring at the maxillary molars can also be performed. The results of this study provide a link among the prior studies carried out with non-human primates, dry skulls and computer models, and describe what actually occurs in the sutures in patients, as the result of RME treatment.

CONCLUSIONS

Rapid maxillary expansion results in significant displacement of the frontonasal, intermaxillary, zygomaticomaxillary and midpalatal sutures in growing children in all three planes of space.

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Dentoskeletal effects of Class II malocclusion treatment with the Twin Block appliance in a Brazilian sample: A prospective study



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Objective: The aim of this study was to assess the dentoskeletal effects of Class II malocclusion treatment performed with the Twin Block appliance.

Methods: The experimental group comprised 20 individuals with initial mean age of 11.76 years and was treated for a period of 1.13 years. The control group comprised 25 individuals with initial mean age of 11.39 years and a follow-up period of 1.07 years. Lateral cephalograms were taken at treatment onset and completion to assess treatment outcomes. Intergroup comparison was performed by means of the chi-square and independent t tests.

Results: The Twin Block appliance did not show significant effects on the maxillary component. The mandibular component showed a statistically significant increase in the effective mandibular length (Co-Gn) and significant improvement in the maxillomandibular relationship. The maxillary and mandibular dentoalveolar components presented a significant inclination of anterior teeth in both arches. The maxillary incisors were lingually tipped and retruded, while the mandibular incisors were labially tipped and protruded.

Conclusions: The Twin Block appliance has great effectiveness for correction of skeletal Class II malocclusion in individuals with growth potential. Most changes are of dentoalveolar nature with a large component of tooth inclination associated with a significant skeletal effect on the mandible.

Keywords: Angle Class II malocclusion. Skull circumference. Functional orthodontic appliances. Prospective studies. Treatment outcome.

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

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INTRODUCTION

Functional appliances have been widely used for treatment of skeletal Class II malocclusion. Even though a few clinicians do not recognize the great effectiveness of these appliances, scientific evidence about the fact that these appliances promote changes in jaw growth remains undefined.^{1,2}

Some authors believe that there is little evidence to support the fact that functional appliances significantly alter mandibular growth.^{3,4} Conversely, other authors suggest that these appliances may have a significant influence over mandibular growth, when used in proper timing.^{5,6,7}

The main changes caused by functional appliances are of dentoalveolar nature, including distalization of the maxillary posterior segment, lingual inclination of maxillary incisors, mesialization of the mandibular posterior segment and buccal inclination of mandibular incisors.⁸ The main vertical changes comprise restriction of vertical development of maxillary molars and stimulation of vertical development of mandibular molars.⁸

However, most of the aforementioned results have been obtained from retrospective studies, and a relatively small number of studies which aimed at assessing dentoskeletal changes were considered as prospective.⁹⁻¹² Thus, this study prospectively assessed the dentoskeletal effects of the Twin Block appliance for treatment of the Class II malocclusion.

MATERIAL AND METHODS

Sample

This study was approved by the Institutional Review Board of Ingá College and all subjects in the sample signed an informed consent form before treatment onset. Sample size calculation was performed to determine the minimum number of individuals in each group. It was calculated considering $\alpha = 5\%$ (type I error), $\beta = 20\%$ (type II error), estimated variability (s) of 1.5¹³ and a minimum difference of 2 mm to be detected (d) between the control and experimental groups. The results revealed a sample of 17 individuals in each group (accounting for occasional losses), with a test power of 80%. A sample of 19 individuals in each group allows a test power of 85%.

The prospective sample comprised 20 dental casts obtained at treatment onset (T_1) and 40 lateral cephalograms obtained at onset (T_1) and completion (T_2) of orthopedic

treatment of 20 individuals with Class II division 1 malocclusion. Twenty-five dental casts and 50 lateral cephalograms obtained from 25 individuals with Class II division 1 malocclusion, who did not receive treatment, comprised the control group. The cephalograms and dental casts in the control group were obtained from the files of the Department of Orthodontics of School of Dentistry — University of São Paulo/Bauru.

The experimental group comprised 20 individuals, 11 males and 9 females, with initial mean age of 11.76 ± 1.64 years presenting Class II division 1 malocclusion at treatment onset and who were treated with the modified Twin Block functional orthopedic appliance. The mean treatment time was 1.13 ± 0.40 years and the final mean age was 12.89 ± 1.56 years. With regard to the initial severity of anteroposterior relationship between the permanent first molars assessed on the dental casts, 9 individuals presented full Class II, 3 presented $\frac{3}{4}$ of Class II, 7 presented $\frac{1}{2}$ Class II and 1 presented $\frac{1}{4}$ of Class II.

The control group comprised 25 untreated individuals, 14 males and 11 females, with Class II division 1 malocclusion, with initial mean age of 11.39 ± 1.35 years. The mean follow-up time was 1.07 ± 0.17 years and the final mean age was 12.46 ± 1.38 years. As for the initial severity of anteroposterior relationship between the permanent first molars assessed on the dental casts, 4 individuals presented full Class II, 6 presented $\frac{3}{4}$ of Class II, 9 presented $\frac{1}{2}$ Class II and 6 presented $\frac{1}{4}$ of Class II.

The inclusion criteria for the experimental group were: 1) presence of Class II division 1 malocclusion assessed on the dental casts and clinically confirmed (no cephalometric criterion was used to determine that individuals presented skeletal Class II with ANB values greater than 4 degrees); 2) crowding in the mandibular arch not greater than 4 mm; 3) no previous orthodontic treatment; 4) presence of clinically observable facial convexity.

Description of the modified Twin-Block appliance

Maxillary portion — composed of an acrylic base covering the hard palate, open at the midpalatal suture line with a Dentaurem® 6.5 mm expanding screw, allowing transverse expansion of the maxillary arch. It contains an anterior Hawley bow used to enhance retention, retract the lip musculature

and control the inclinations of maxillary incisors. The appliance has simple coils on the palatal region of maxillary central and lateral incisors for tongue pressure control and teeth uprighting. The appliance retention is achieved in posterior teeth with Benac clasps, which allow activation and present good flexibility due to the great amount of wire employed for fabrication. The acrylic blocks are placed on the occlusal surface of posterior teeth with enough height to allow disocclusion of anterior teeth. The anterior portion of planes present an angle of 70 degrees, which, in combination with the mandibular planes, keeps the mandible protruded (Figs 1 and 2).

The mandibular portion is composed of an acrylic base on the lingual alveolar ridge, with anterior Hawley bow to control the inclination of incisors. The presence of a Dentaurem[®] 5.5-mm expanding screw on the midline allows correction of small lingual inclinations of posterior teeth. Benac clasps are used for appliance retention on the posterior portion, and, if the bow is not sufficient in the anterior portion, an acrylic coverage should be applied on the edges of mandibular incisors. The planes are located ahead, at the region of the first premolars, and are extended up to the canines in order to achieve greater strength. They are fabricated at 70 degrees to fit with the maxillary portion of the appliance, keeping the mandible in a more anterior position. Plane height is compatible with the upper plane, without contact with teeth

in the maxillary arch (Figs 1 and 2). The individuals were instructed to use the modified Twin Block for an approximate period of 20h/day.

Lateral cephalograms

Aiming to verify the dentoskeletal changes of the modified Twin Block appliance, lateral cephalograms obtained at treatment onset and completion were assessed and compared to the control group. All radiographic images were obtained with the lips at rest and in maximum intercuspation, with the aid of the Broadbent cephalostat to standardize head positioning. All cephalograms in the sample were performed in three difference machines and the magnification of each appliance was determined in order to allow greater accuracy of results. The different machines presented distinct magnification percentages which ranged from 6% to 10.94%.

Cephalometric tracing and achievement of measurements

The cephalograms were digitized at a resolution of 9600 x 4800 dpi in a Microtek ScanMaker i800 scanner (Microtek International, Inc., Carson, CA, USA) connected to a Pentium microcomputer. The images were transferred to the Dolphin Imaging Premium 10.5 software (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA) through which the cephalometric points of interest were marked and measurements involving the planes and lines were obtained.



Figure 1 - Modified Twin Block appliance.

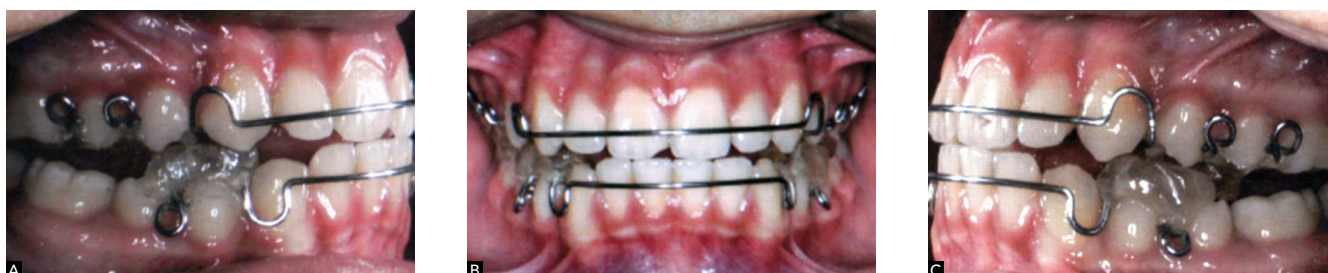


Figure 2 - Twin Block appliance in use - A) Right lateral view. B) Frontal view. C) Left lateral view.

Cephalometric measurements employed (Figs 3, 4, 5 and 6)

The following cephalometric measurements were used in this study:

1. Maxillary component: SNA, A-Nperp and Co-A.
2. Mandibular component: SNB, P-Nperp and Co-Gn.
3. Maxillomandibular relationship: ANB and Wits.
4. Growth pattern: SN.GoGn, SN.GoMe, SN.Ocl, FMA and LAFH.
5. Maxillary dentoalveolar component: 1.NA, 1-NA, 1-Aperp, 1.PP and 1-PP.
6. Mandibular dentoalveolar component: 1.NB, 1-NB, 1-AP and IMPA.
7. Dental relationships: overjet, overbite and molar relationship.

STATISTICAL ANALYSIS

Method error

To evaluate the intra-examiner error, all measurements were repeated by the same investigator on 30 lateral cephalograms randomly selected after a three-week interval. Application of the mathematical formula proposed by Dahlberg ($Se^2 = \sum d^2/2n$) allowed estimation of casual errors.¹⁴ Systematic errors were assessed by the dependent t test.^{15,16}

Intergroup comparison

The Kolmogorov-Smirnov test was applied to analyze if cephalometric data in the experimental and control groups presented normal distribution. The results revealed that the cephalometric variables presented normal distribution in both groups and in all periods analyzed ($P > 0.05$). Thus, parametric tests were used for intergroup comparison. The compatibility between experimental and control groups in relation to the initial (T_1) and final mean ages (T_2) and the treatment/follow-up time was assessed by the independent t test. The chi-square test was used to verify the compatibility between groups with regard to gender distribution and anteroposterior severity existing between molars.

The independent t test was used for intergroup comparison at the initial (T_1) and final periods (T_2) and to assess changes between the initial and final periods ($T_2 - T_1$) in both groups. Bonferroni correction was used for false-positive control (type I error), and differences were considered statistically significant at $P < (0.05/24) = 0.002$.

All statistical tests were performed by means of the Statistica for Windows 7.0 software (Stat Soft Inc., Tulsa, Oklahoma, USA).

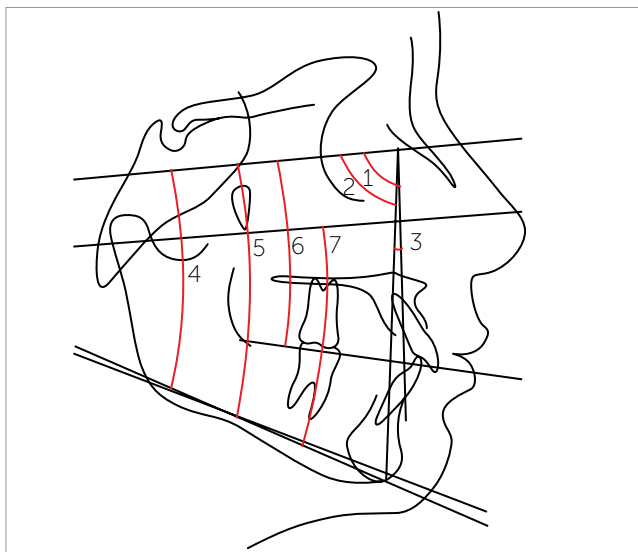


Figure 3 - Skeletal angular cephalometric measurements: 1) SNA; 2) SNB; 3) ANB; 4) SN.GoMe; 5) SN.GoGn; 6) SN.Ocl; 7) FMA.

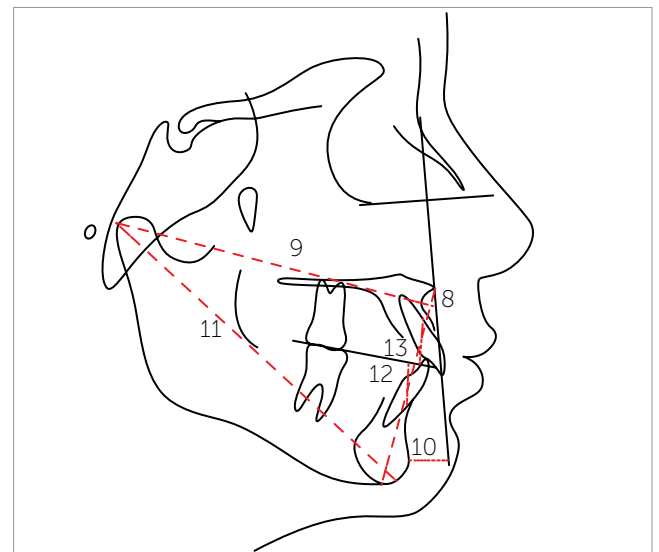


Figure 4 - Linear skeletal cephalometric measurements: 8) A-Nperp; 9) Co-A; 10) P-Nperp; 11) Co-Gn; 12) Wits; 13) LAFH.

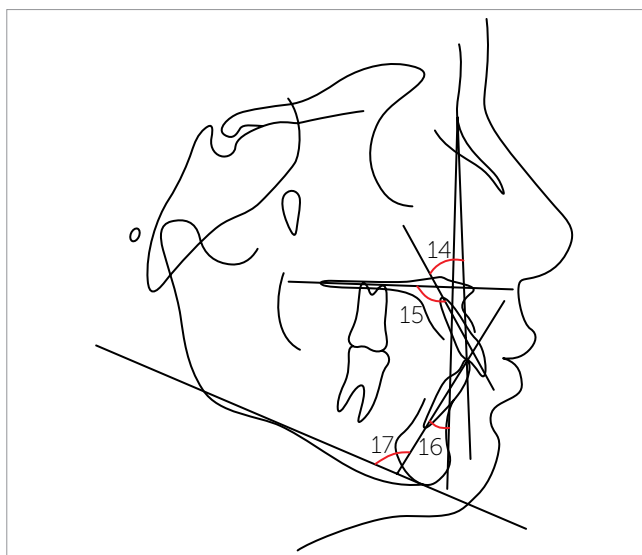


Figure 5 - Angular dental cephalometric measurements: 14) 1-NA; 15) 1-PP; 16) 1-NB; 17) IMPA.

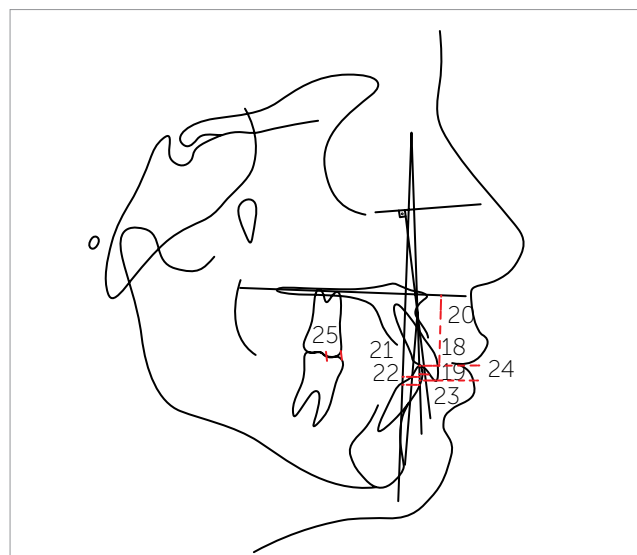


Figure 6 - Linear dental cephalometric measurements: 18) 1-NA; 19) 1-Aperp; 20) 1-PP; 21) 1-NB; 22) 1-AP; 23) overjet; 24) overbite; 25) molar relationship.

RESULTS

Three variables (SNA, SN.GoGn and LAFH) presented systematic error ($P < 0.05$) and the amplitude of casual errors ranged from 0.32 (ANB) to 2.39 (LAFH).

The experimental and control groups were compatible in initial and final age, treatment/follow-up time, gender distribution and severity of anteroposterior relationship existing between molars (Tables 1, 2 and 3).

At treatment onset (T_1), the experimental and control groups presented moderate cephalometric compatibility, with the variables ANB and Wits in the maxillomandibular relationship component presenting the worst relationship between jaws in the experimental group ($P < 0.002$). In the maxillary dentoalveolar component, the 1-Aperp variable revealed that maxillary incisors in the experimental group were significantly more buccally inclined and protruded in the maxilla ($P < 0.002$). As for the dental relationship component, the overjet variable significantly increased in relation to the control group ($P < 0.002$) (Table 4).

At treatment completion (T_2), the growth pattern, evaluated by the LAFH variable, was significantly greater in the experimental group in comparison to the control group. In the mandibular dentoalveolar component, the experimental group presented significantly more protruded and buccally inclined mandibular incisors in comparison to the control group. In the evaluation of dental relationships, the experimental group presented significantly smaller molar relationship in comparison to the control group (Table 5).

Comparison of dentoskeletal changes (T_2-T_1) between the experimental and control groups revealed that, in relation to the mandibular component, the experimental group exhibited a significantly greater increase in mandibular length (Co-Gn). As for the growth pattern component, the Sn.Ocl variable exhibited significantly greater increase in the experimental group in comparison to the control group. With regard to the maxillary dentoalveolar component, the experimental group presented greater and significant lingual inclination and retrusion of maxillary incisors in comparison to the control group. In the mandibular dentoalveolar component, the experimental group exhibited greater and significant buccal inclination and protrusion of mandibular incisors in comparison to the control group. In the analysis of dental relationships, the experimental group exhibited significantly greater reduction in overjet and molar relationship when compared to the control group (Table 6).

DISCUSSION

The use of removable functional orthopedic appliances in growing individuals with skeletal Class II has demonstrated to have some advantages promoted by treatment of Class II malocclusion in two stages (functional orthopedics and fixed appliance).^{11,17} Reduction in overjet at early ages, better relationship between the jaws, reduction in facial convexity and shorter treatment time with fixed appliances are factors that encourage treatment of Class II malocclusion in two stages.⁹

Table 1 - Evaluation of compatibility between groups considering initial age, final age and treatment/follow-up time (independent t test).

Variables (years)	Experimental group (n = 20)	Control group (n = 25)	P
	Mean $\pm$ S.D.	Mean $\pm$ S.D.	
Initial age	11.76 $\pm$ 1.64	11.39 $\pm$ 1.35	0.4063
Final age	12.89 $\pm$ 1.56	12.45 $\pm$ 1.38	0.3239
Treatment/follow-up time	1.13 $\pm$ 0.40	1.07 $\pm$ 0.17	0.4773

Table 2 - Comparison of sex distribution in the two groups (chi-square test).

Group	Sex		Total
	Female	Male	
Experimental	9	11	20
Control	11	14	25
Total	20	25	45
$\chi^2 = 0.005$; df = 1; P = 0.9465			

Table 3 - Result of the chi-square test for comparison between experimental and control groups with regard to the severity of existing anteroposterior molar relationship.

Severity	Experimental group (n = 20)	Control group (n = 25)
¼ Class II	1	6
½ Class II	7	9
¾ Class II	3	6
Full Class II	9	4
$\chi^2 = 6.2663$; df = 3; P = 0.0993		

Table 4 - Results of the independent t test for comparison between experimental and control groups at the initial period (T₁).

Variables	Experimental Group (T ₁) (n = 20)	Control Group (T ₁) (n = 25)	p
	Mean ± S.D.	Mean ± S.D.	
Maxillary component			
SNA (degrees)	84.51 ± 3.51	83.30 ± 3.16	0.2270
A-Nperp (mm)	0.78 ± 2.98	-0.18 ± 2.70	0.2618
Co-A (mm)	85.45 ± 3.38	83.67 ± 4.80	0.1686
Mandibular component			
SNB (degrees)	77.33 ± 4.10	78.59 ± 3.49	0.2723
P-Nperp (mm)	-8.95 ± 6.64	-6.30 ± 4.83	0.1287
Co-Gn (mm)	108.49 ± 6.60	108.14 ± 6.27	0.8570
Maxillomandibular relationship			
ANB (degrees)	7.19 ± 2.27	4.69 ± 1.66	0.0001
Wits (mm)	3.84 ± 2.65	0.50 ± 2.34	0.0001
Growth pattern			
SN.GoGn (degrees)	30.46 ± 5.24	29.88 ± 4.95	0.7049
SN.Ocl (degrees)	13.00 ± 5.20	14.57 ± 2.99	0.2095
FMA (degrees)	26.58 ± 4.85	25.83 ± 4.06	0.5743
LAFH (mm)	61.16 ± 4.03	58.49 ± 4.55	0.0461
Maxillary dentoalveolar component			
1.NA (degrees)	29.48 ± 6.75	24.73 ± 6.29	0.0190
1-NA (mm)	5.03 ± 2.10	3.44 ± 1.87	0.0107
1-Aperp (mm)	6.23 ± 1.74	4.40 ± 1.05	0.0001
1.PP (degrees)	120.68 ± 5.63	115.20 ± 5.80	0.0027
1-PP (mm)	26.35 ± 1.86	25.37 ± 2.76	0.1837
Mandibular dentoalveolar component			
1-NB (mm)	5.14 ± 2.44	3.92 ± 1.97	0.0713
1.NB (degrees)	26.18 ± 6.98	24.40 ± 6.34	0.3760
1-AP (mm)	-0.15 ± 2.12	0.37 ± 2.16	0.4213
IMPA (degrees)	95.92 ± 8.16	93.47 ± 6.59	0.2715
Dental relationships			
Overjet (mm)	9.16 ± 2.10	5.61 ± 2.61	0.0000
Overbite (mm)	4.59 ± 2.50	3.29 ± 1.73	0.0464
Molar relationship (mm)	1.90 ± 1.54	0.40 ± 1.55	0.0024

Table 5 - Results of the independent t test for comparison between experimental and control groups at the final period (T₂).

Variables	Experimental Group (T ₂) (n = 20)	Control Group (T ₂) (n = 25)	p
	Mean ± S.D.	Mean ± S.D.	
Maxillary component			
SNA (degrees)	84.18 ± 4.55	82.99 ± 3.26	0.3117
A-Nperp (mm)	0.50 ± 3.36	-0.48 ± 2.51	0.2728
Co-A (mm)	87.26 ± 3.68	84.84 ± 4.39	0.0562
Mandibular component			
SNB (degrees)	78.61 ± 4.66	78.84 ± 3.90	0.8523
P-Nperp (mm)	-7.08 ± 7.14	-5.93 ± 4.81	0.5256
Co-Gn (mm)	115.00 ± 6.72	110.48 ± 6.21	0.0242
Maxillomandibular relationship			
ANB (degrees)	5.59 ± 1.83	4.14 ± 1.69	0.0087
Wits (mm)	1.67 ± 3.15	0.16 ± 3.02	0.1083
Growth pattern			
SN.GoGn (degrees)	29.94 ± 5.39	28.96 ± 4.79	0.5223
SN.Ocl (degrees)	14.37 ± 5.13	13.70 ± 3.02	0.5823
FMA (degrees)	25.91 ± 4.58	25.26 ± 3.40	0.5885
LAFH (mm)	64.34 ± 4.00	59.02 ± 4.43	0.0014
Maxillary dentoalveolar component			
1.NA (degrees)	22.42 ± 5.11	25.13 ± 3.92	0.0502
1-NA (mm)	3.25 ± 1.78	4.04 ± 1.61	0.1265
1-Aperp (mm)	4.78 ± 1.52	4.88 ± 1.22	0.8001
1.PP (degrees)	113.68 ± 4.38	114.96 ± 4.19	0.3221
1-PP (mm)	27.84 ± 2.09	26.02 ± 2.67	0.0167
Mandibular dentoalveolar component			
1-NB (mm)	7.10 ± 2.27	4.10 ± 1.74	0.0000
1.NB (degrees)	32.35 ± 6.28	25.25 ± 5.10	0.0001
1-AP (mm)	2.85 ± 2.10	0.74 ± 2.00	0.0013
IMPA (degrees)	101.43 ± 6.95	94.68 ± 5.02	0.0005
Dental relationships			
Overjet (mm)	3.88 ± 1.46	5.43 ± 2.09	0.0071
Overbite (mm)	3.04 ± 1.44	3.30 ± 1.53	0.5633
Molar relationship (mm)	-1.87 ± 2.24	0.42 ± 1.22	0.0001

Conversely, some authors have demonstrated that treatment of Class II malocclusion performed in one stage in the permanent dentition (fixed appliance) is more efficient in comparison to treatment performed in two stages, given that similar occlusal results are obtained in significantly shorter treatment time.^{18,19,20}

Investigations into the actual dentoskeletal changes obtained with the Twin Block appliance in the first treatment stage did not reveal any restriction of anterior maxillary displacement (Table 6). This result suggests that treatment of Class II malocclusion with the Twin Block did not present any significant extraoral effect, as reported in previous studies.^{17,21}

Evaluation of the mandibular component revealed a statistically significant increase of 4.17 mm in the mandibular length (Co-Gn) with anterior displacement of the Gonion, two changes that are desirable in the treatment of individuals with skeletal Class II malocclusion (Table 6). It was not possible to determine if the increase in the Co-Gn variable was caused by an increase in mandibular length or mandibular repositioning. Some authors have also evidenced similar changes in relation to mandibular length.^{9,11,17,22} However, the functional orthopedic appliances promote a greater increase in mandibular length within shorter treatment time, yet the final mandibular length at completion of the growth period is not significantly greater in

Table 6 - Results of the independent t test for comparison of changes (T_2-T_1) between experimental and control groups.

Variables	Experimental Group (T ₂) (n = 20)	Control Group (T ₂) (n = 25)	p
	Mean ± S.D.	Mean ± S.D.	
Maxillary component			
SNA (degrees)	-0.33 ± 1.69	-0.30 ± 1.47	0.9564
A-Nperp (mm)	-0.29 ± 2.46	-0.29 ± 1.90	0.9915
Co-A (mm)	1.80 ± 2.60	1.17 ± 1.23	0.2870
Mandibular component			
SNB (degrees)	1.27 ± 1.41	0.26 ± 1.29	0.0152
P-Nperp (mm)	1.88 ± 4.35	0.37 ± 2.82	0.1674
Co-Gn (mm)	6.51 ± 3.13	2.34 ± 1.56	0.0000
Maxillomandibular relationship			
ANB (degrees)	-1.60 ± 1.55	-0.54 ± 1.10	0.0108
Wits (mm)	-2.16 ± 2.78	-0.34 ± 2.30	0.0210
Growth pattern			
SN.GoGn (degrees)	-0.53 ± 1.67	-0.92 ± 2.09	0.4911
SN.Ocl (degrees)	1.37 ± 2.38	-0.87 ± 1.87	0.0010
FMA (degrees)	-0.68 ± 2.21	-0.57 ± 2.57	0.8877
LAFH (mm)	3.18 ± 3.12	1.49 ± 1.44	0.0201
Maxillary dentoalveolar component			
1.NA (degrees)	-7.06 ± 6.11	0.40 ± 4.38	0.0000
1-NA (mm)	-1.77 ± 1.62	0.60 ± 1.45	0.0000
1-Aperp (mm)	-1.44 ± 1.33	0.49 ± 1.16	0.0000
1.PP (degrees)	-7.00 ± 6.41	-0.24 ± 3.93	0.0001
1-PP (mm)	1.50 ± 1.64	0.65 ± 1.27	0.0583
Mandibular dentoalveolar component			
1-NB (mm)	1.96 ± 1.83	0.18 ± 0.95	0.0001
1.NB (degrees)	6.17 ± 5.96	0.85 ± 3.29	0.0004
1-AP (mm)	3.00 ± 1.97	0.36 ± 1.10	0.0000
IMPA (degrees)	5.51 ± 6.33	1.20 ± 3.53	0.0060
Dental relationships			
Overjet (mm)	-5.29 ± 2.20	-0.18 ± 1.28	0.0000
Overbite (mm)	-1.55 ± 2.73	0.01 ± 1.39	0.0169
Molar relationship (mm)	-3.76 ± 2.32	0.02 ± 1.39	0.0000

comparison to untreated individuals. This characteristic of functional appliances is known in the literature as the mortgage of mandibular growth.^{2,23} Improvement in mandibular retrognathism was also observed in individuals in the experimental group, who presented a greater increase in the SNB variable (1.01 degrees) when compared to the control group (Table 6). This change probably contributed to reduce facial convexity in individuals in the experimental group.

A probable lingual movement of the roots of mandibular incisors may promote alveolar remodeling, changing the position of point B to a more posterior position and, as a consequence, reducing the SNB variable. The mandibular incisors presented significant buccal

inclination and protrusion, yet evidenced an increase in the SNB angle (Table 6). Previous studies also found similar changes in the evaluation of cephalometric effects promoted by the use of functional appliances.^{11,21}

Evaluation of the maxillomandibular relationship component revealed that mandibular growth and/or repositioning did not promote significant changes in ANB and Wits variables with consequent reduction in skeletal discrepancy between jaws in individuals in the experimental group (Table 6). This result does not agree with previous studies, since several studies in the literature demonstrate the great effectiveness of functional appliances in achieving a better relationship between maxilla and mandible.^{17,24,25}

With regard to growth pattern, there was a non-significant increase in LAFH (1.69 mm) in individuals in the experimental group compared to the control group, with consequent clockwise rotation of the occlusal plane, as observed by the significant increase in the SN.Ocl variable (Table 6). These effects were probably caused by selective wear of the acrylic in contact with the mandibular posterior teeth, allowing greater vertical development of these teeth, which contributes for correction of Class II relationship, curve of Spee and deep bite in the individuals.^{26,27,28}

The maxillary and mandibular dentoalveolar components presented a significant component of inclination of anterior teeth in both arches. The maxillary incisors were lingually inclined and retruded, while the mandibular incisors were buccally inclined and protruded (Table 6). These dentoalveolar changes significantly contributed for correction of the overjet.^{9,17,22} However, excessive inclination of incisors should be carefully controlled, since they substantially reduce the potential of changes of orthopedic nature.⁹

In the evaluation of dental relationships, there was a significant reduction of 5.11 mm in the overjet and of 3.78 mm in molar relationship in comparison to the control group. These changes contribute to correct the anteroposterior discrepancy in individuals with Class II malocclusion (Table 6). These results represent a desirable consequence of treatment of skeletal Class II malocclusion, and are established by the combination of dentoalveolar and skeletal changes that occurred in the experimental group.^{29,30}

CONCLUSION

Based on the methods applied and the results achieved, it is reasonable to conclude that the Twin Block appliance presented great effectiveness for correction of Class II malocclusion in growing individuals. Most changes were of dentoalveolar nature with a marked component of dental inclination associated with a significant skeletal effect on the mandible.

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Dental and skeletal changes in patients with mandibular retrognathism following treatment with Herbst and pre-adjusted fixed appliance

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Objective: To assess the dentoskeletal changes observed in treatment of Class II, division 1 malocclusion patients with mandibular retrognathism. Treatment was performed with the Herbst orthopedic appliance during 13 months (phase I) and pre-adjusted orthodontic fixed appliance (phase II).

Methods: Lateral cephalograms of 17 adolescents were taken in phase I onset (T_1) and completion (T_2); in the first thirteen months of phase II (T_3) and in phase II completion (T_4). Differences among the cephalometric variables were statistically analyzed (Bonferroni variance and multiple comparisons).

Results: From T_1 to T_4 , 42% of overall maxillary growth was observed between T_1 and T_2 ($P < 0.01$), 40.3% between T_2 and T_3 ($P < 0.05$) and 17.7% between T_3 and T_4 (n.s.). As for overall mandibular movement, 48.2% was observed between T_1 and T_2 ($P < 0.001$) and 51.8% between T_2 and T_4 ($P < 0.01$) of which 15.1% was observed between T_2 and T_3 (n.s.) and 36.7% between T_3 and T_4 ($P < 0.01$). Class II molar relationship and overjet were properly corrected. The occlusal plane which rotated clockwise between T_1 and T_2 , returned to its initial position between T_2 and T_3 remaining stable until T_4 . The mandibular plane inclination did not change at any time during treatment.

Conclusion: Mandibular growth was significantly greater in comparison to maxillary, allowing sagittal maxillomandibular adjustment. The dentoalveolar changes (upper molar) that overcorrected the malocclusion in phase I, partially recurred in phase II, but did not hinder correction of the malocclusion. Facial type was preserved.

Keywords: Angle Class II malocclusion. Orthopedics. Orthodontics.

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

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INTRODUCTION

Growing patients with Class II malocclusion and mandibular retrognathism may be treated with a variety of techniques, as described in the literature. Some of the techniques include treatment performed with an orthopedic phase employing appliances such as the Herbst. This treatment has been widely studied by Pancherz¹⁻⁴ and other researchers⁵⁻²² who took several aspects into consideration and revealed that this type of treatment not only represents an alternative to the correction of Class II malocclusion, but also preserves the stomatognathic system. However, with regard to Brazilian individuals, these results are questioned: Are treatment effects skeletal or dentoalveolar? Is the mandibular growth curve modified when stimulated by the Herbst appliance? Are the obtained results lost after the appliance is removed? The complexity of clarifying the referred doubts lays in the difficulty of performing longitudinal studies in homogeneous casuistries. With a view to eliminating the tendency towards including only successful cases and, thus, confuse the results, the ideal would be that prospective studies were conducted with groups of consecutive patients. From this point of view, in 2007, a study²³ was carried out to assess and compare, in patients treated during growth spurt, the dentoskeletal changes observed in the Herbst active phase and during a period of same duration after the appliance had been removed. The obtained results were the motivation to perform the present study which aims at assessing full treatment performed in adolescents in two phases: phase I – orthopedic with Herbst appliance and phase II – orthodontic with pre-adjusted fixed appliance.

MATERIAL AND METHODS

The sample comprised 17 Brazilian adolescent patients (12 men and 5 women), with mean age of 12 years and 4 months $\pm$ 1 year and 2 months, and bone age corresponding to the growth spurt, as revealed by a hand-wrist radiograph. The patients were selected according to the following inclusion criteria: individuals with mandibular retrognathism and Angle Class II, division 1 malocclusion greater than half-cusp (> 3 mm); individuals with overjet > 5 mm (permanent dentition); with model discrepancy under 4 mm; with clinical recommendation for mandibular advancement to be performed with functional orthopedic appliance. Individuals with absence of teeth, dental fractures and dental caries were excluded. Treatment was carried out in two phases. Initially, the orthopedic phase (phase I)

performed with Herbst functional orthopedic appliance placed onto acrylic splints associated with maxillary expansion screw.²⁴ The objective was to correct the transversal discrepancy,²⁵ activating the expansion screw during the first month of treatment. The appliance was made according to a wax bite registration obtained with 6 mm of initial advancement, and progressive advancements of 2 mm every 2 months, according to individual needs. This phase lasted for an average of 13.9 ± 2.1 months. Thereafter, the orthodontic phase (phase II) was performed with pre-adjusted fixed appliance and aimed at leveling and aligning the upper and lower teeth as well as at obtaining functional occlusion with adequate overjet and overbite. This phase lasted for 46 months.

Complete orthodontic documentation (panoramic and hand-wrist radiographs, lateral and frontal cephalograms; intra and extraoral photographs; study casts) was prepared for all patients at four stages: T₁, immediately before treatment onset; T₂, after 13 months using the Herbst appliance, which represented the end of phase I; T₃, 13 months after phase II or orthodontic phase had begun; and T₄, phase II completion, totalizing a period of 33 months. All 68 lateral cephalograms were manually traced by the same operator at monthly intervals. They were analyzed with regard to the cephalometric variables of sagittal changes analysis (SO-analysis) suggested by Pancherz⁴ (Figs 1 and 2).

Patients' guardians signed an informed consent form, agreeing with all stages of the study and the posterior disclosure of results. The project was approved by the Institutional Review Board of the School of Dentistry/USP and registered under protocol 109/06.

STATISTICAL ANALYSIS

Method error assessment (Dahlberg²⁶) was performed in 11.8% of the sample.

The values of each measure and the relation of each moment assessed by means and standard deviations were expressed and compared to the measurements taken between the moments of assessment using the analysis of variance carried out with repeated measures. For measurements that presented statistically significant differences between the moments of assessment, Bonferroni multiple comparisons were performed. They revealed in which moments these differences occurred. The tests were performed with a significance level set at 5%.

RESULTS

For a better understanding of the characteristics of each moment of growth (Fig 2) and the differences between them, the results are presented in three tables. Table 1 presents the measures, the relation between measurements at each moment of assessment and the result of the analysis of variance.

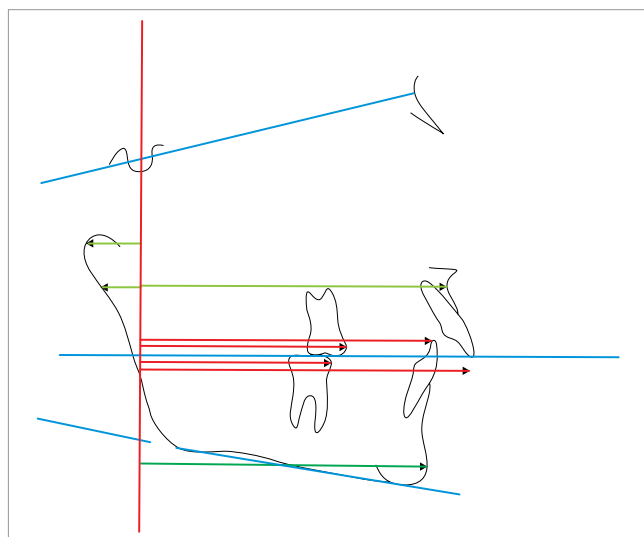


Figure 1 - Analysis of sagittal changes (SO-analysis) of Pancherz.

The results of Bonferroni multiple comparisons are presented in Table 2, whereas the results presenting differences in the relation between measures are shown in Table 3.

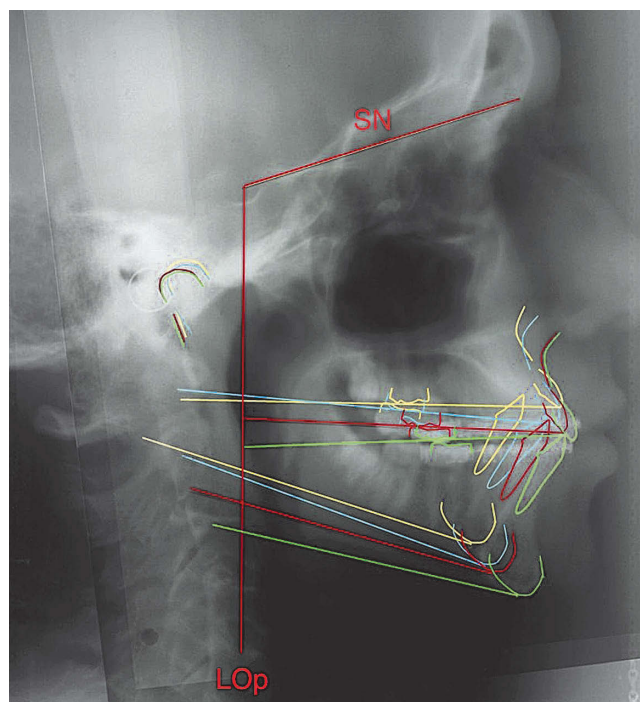


Figure 2 - Superimposition of tracings (according to analysis of Pancherz⁴), of one of the patients from the sample, in all four observation stages: T_1 = yellow, T_2 = blue, T_3 = red and T_4 = green.

Table 1 - Measures and relations between values obtained at each moment of assessment and result of the analysis of variance.

Variable	Orthopedic phase		Orthodontic phase		N	p
	T ₁	T ₂	T ₃	T ₄		
	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.		
SN.PM	32.59 ± 5.42	32.56 ± 5.59	31.88 ± 5.36	32.03 ± 6.26	17	0.439
ui/Lop	90.77 ± 5.18	90.47 ± 6.55	92.15 ± 6.78	93.79 ± 6.28	17	<0.001
li/Lop	81.62 ± 5.95	87.82 ± 6.50	87.97 ± 6.60	90.06 ± 6.20	17	<0.001
um/Lop	57.12 ± 4.31	57.21 ± 5.02	59.56 ± 4.91	62.35 ± 5.45	17	<0.001
lm/Lop	55.53 ± 4.70	61.32 ± 5.24	62.59 ± 5.14	65.59 ± 5.61	17	<0.001
ss/Lop	81.24 ± 3.47	82.50 ± 3.94	83.71 ± 4.06	84.24 ± 4.40	17	<0.001
pg/Lop	83.15 ± 5.30	87.59 ± 5.85	88.59 ± 6.04	91.68 ± 6.19	17	<0.001
ar/Lop	10.59 ± 3.73	10.24 ± 3.70	10.44 ± 4.12	9.88 ± 4.14	17	0.241
co/Lop	12.94 ± 3.62	12.91 ± 3.58	13.29 ± 3.63	13.56 ± 4.08	17	0.319
SN.LO	20.29 ± 3.72	23.15 ± 4.63	20.79 ± 4.47	19.06 ± 4.72	17	<0.001
ui/Lop-li/Lop	9.15 ± 2.74	2.65 ± 1.23	4.18 ± 1.20	3.74 ± 0.90	17	<0.001
um/Lop-lm/Lop	1.59 ± 1.61	-4.12 ± 2.10	-3.03 ± 1.58	-3.24 ± 1.15	17	<0.001
pg/Lop+ar/Lop	93.74 ± 5.18	97.82 ± 5.76	99.03 ± 6.74	101.56 ± 7.66	17	<0.001
pg/Lop+co/Lop	96.09 ± 5.12	100.50 ± 5.69	101.88 ± 6.62	105.24 ± 7.95	17	<0.001
ui/Lop-ss/Lop	9.53 ± 2.70	7.97 ± 3.12	8.44 ± 3.28	9.56 ± 2.93	17	0.022
li/Lop-pg/Lop	-1.53 ± 5.83	0.24 ± 5.86	-0.62 ± 5.61	-1.62 ± 5.63	17	0.031
um/Lop-ss/Lop	-24.12 ± 2.24	-25.29 ± 2.30	-24.15 ± 2.18	-21.88 ± 2.71	17	<0.001
lm/Lop-pg/Lop	-27.62 ± 3.74	-26.26 ± 4.20	-26.00 ± 4.46	-26.09 ± 4.92	17	0.008

Table 2 - Result of Bonferroni multiple comparisons for measurements that presented differences during treatment.

Variable	Comparison	Mean difference	Standard error	p	CI (95%)	
					Lower	Upper
ui/Lop	$T_1 - T_2$	0.29	0.56	> 0.999	-1.40	1.99
	$T_1 - T_3$	-1.38	0.76	0.516	-3.66	0.89
	$T_1 - T_4$	-3.03	0.70	0.003	-5.14	-0.92
	$T_2 - T_3$	-1.68	0.49	0.020	-3.14	-0.21
	$T_2 - T_4$	-3.32	0.73	0.002	-5.51	-1.14
	$T_3 - T_4$	-1.65	0.52	0.034	-3.20	-0.10
li/Lop	$T_1 - T_2$	-6.21	0.48	< 0.001	-7.66	-4.75
	$T_1 - T_3$	-6.35	0.65	< 0.001	-8.30	-4.41
	$T_1 - T_4$	-8.44	0.86	< 0.001	-11.01	-5.87
	$T_2 - T_3$	-0.15	0.56	> 0.999	-1.83	1.54
	$T_2 - T_4$	-2.24	0.79	0.072	-4.61	0.14
	$T_3 - T_4$	-2.09	0.59	0.016	-3.86	-0.31
um/Lop	$T_1 - T_2$	-0.09	0.40	> 0.999	-1.29	1.11
	$T_1 - T_3$	-2.44	0.44	< 0.001	-3.75	-1.13
	$T_1 - T_4$	-5.24	0.74	< 0.001	-7.45	-3.02
	$T_2 - T_3$	-2.35	0.37	< 0.001	-3.46	-1.25
	$T_2 - T_4$	-5.15	0.85	< 0.001	-7.70	-2.59
	$T_3 - T_4$	-2.79	0.65	0.003	-4.74	-0.85
lm/Lop	$T_1 - T_2$	-5.79	0.50	< 0.001	-7.29	-4.30
	$T_1 - T_3$	-7.06	0.57	< 0.001	-8.76	-5.36
	$T_1 - T_4$	-10.06	1.02	< 0.001	-13.13	-6.99
	$T_2 - T_3$	-1.27	0.45	0.073	-2.61	0.08
	$T_2 - T_4$	-4.27	0.98	0.003	-7.22	-1.31
	$T_3 - T_4$	-3.00	0.69	0.003	-5.07	-0.93
ss/Lop	$T_1 - T_2$	-1.27	0.30	0.004	-2.17	-0.36
	$T_1 - T_3$	-2.47	0.45	< 0.001	-3.82	-1.12
	$T_1 - T_4$	-3.00	0.66	0.002	-4.99	-1.01
	$T_2 - T_3$	-1.21	0.37	0.032	-2.33	-0.08
	$T_2 - T_4$	-1.74	0.64	0.094	-3.67	0.20
	$T_3 - T_4$	-0.53	0.43	> 0.999	-1.81	0.75
pg/Lop	$T_1 - T_2$	-4.44	0.53	< 0.001	-6.02	-2.86
	$T_1 - T_3$	-5.44	0.71	< 0.001	-7.57	-3.31
	$T_1 - T_4$	-8.53	1.11	< 0.001	-11.86	-5.20
	$T_2 - T_3$	-1.00	0.46	0.280	-2.40	0.40
	$T_2 - T_4$	-4.09	1.00	0.005	-7.10	-1.08
	$T_3 - T_4$	-3.09	0.70	0.003	-5.19	-0.99
SN.LO	$T_1 - T_2$	-2.85	0.85	0.023	-5.40	-0.31
	$T_1 - T_3$	-0.50	0.75	> 0.999	-2.76	1.76
	$T_1 - T_4$	1.24	0.78	0.801	-1.12	3.59
	$T_2 - T_3$	2.35	0.32	< 0.001	1.39	3.32
	$T_2 - T_4$	4.09	0.86	0.001	1.51	6.67
	$T_3 - T_4$	1.74	0.61	0.068	-0.09	3.56

Table 3 - Result of Bonferroni multiple comparisons for relations between measures that presented differences during treatment.

Variable	Comparison	Mean difference	Standard error	p	CI (95%)	
					Lower	Upper
ui/Lop-li/Lop	$T_1 - T_2$	6.50	0.71	< 0.001	4.37	8.64
	$T_1 - T_3$	4.97	0.78	< 0.001	2.64	7.31
	$T_1 - T_4$	5.41	0.75	< 0.001	3.16	7.66
	$T_2 - T_3$	-1.53	0.49	0.041	-3.01	-0.05
	$T_2 - T_4$	-1.09	0.43	0.129	-2.37	0.20
	$T_3 - T_4$	0.44	0.30	0.963	-0.46	1.34
um/Lop-lm/Lop	$T_1 - T_2$	5.71	0.47	< 0.001	4.30	7.11
	$T_1 - T_3$	4.62	0.43	< 0.001	3.33	5.90
	$T_1 - T_4$	4.82	0.40	< 0.001	3.61	6.03
	$T_2 - T_3$	-1.09	0.24	0.002	-1.81	-0.37
	$T_2 - T_4$	-0.88	0.47	0.482	-2.30	0.54
	$T_3 - T_4$	0.21	0.33	> 0.999	-0.78	1.19
pg/Lop+ar/Lop	$T_1 - T_2$	-4.09	0.44	< 0.001	-5.42	-2.75
	$T_1 - T_3$	-5.29	0.69	< 0.001	-7.36	-3.23
	$T_1 - T_4$	-7.82	1.05	< 0.001	-10.98	-4.67
	$T_2 - T_3$	-1.21	0.56	0.286	-2.90	0.49
	$T_2 - T_4$	-3.74	0.96	0.008	-6.61	-0.86
	$T_3 - T_4$	-2.53	0.56	0.002	-4.22	-0.84
pg/Lop+co/Lop	$T_1 - T_2$	-4.41	0.37	< 0.001	-5.52	-3.30
	$T_1 - T_3$	-5.79	0.61	< 0.001	-7.63	-3.96
	$T_1 - T_4$	-9.15	1.12	< 0.001	-12.52	-5.77
	$T_2 - T_3$	-1.38	0.51	0.096	-2.93	0.16
	$T_2 - T_4$	-4.74	1.06	0.002	-7.91	-1.56
	$T_3 - T_4$	-3.35	0.71	0.001	-5.50	-1.21
ui/Lop-ss/Lop	$T_1 - T_2$	1.56	0.49	0.035	0.08	3.03
	$T_1 - T_3$	1.09	0.71	0.857	-1.04	3.21
	$T_1 - T_4$	-0.03	0.70	> 0.999	-2.12	2.06
	$T_2 - T_3$	-0.47	0.44	> 0.999	-1.80	0.86
	$T_2 - T_4$	-1.59	0.59	0.095	-3.36	0.18
	$T_3 - T_4$	-1.12	0.46	0.155	-2.49	0.25
li/Lop-pg/Lop	$T_1 - T_2$	-1.77	0.44	0.006	-3.08	-0.45
	$T_1 - T_3$	-0.91	0.76	> 0.999	-3.20	1.37
	$T_1 - T_4$	0.09	0.77	> 0.999	-2.24	2.41
	$T_2 - T_3$	0.85	0.59	> 0.999	-0.92	2.63
	$T_2 - T_4$	1.85	0.66	0.076	-0.13	3.84
	$T_3 - T_4$	1.00	0.37	0.092	-0.11	2.11
um/Lop-ss/Lop	$T_1 - T_2$	1.18	0.30	0.008	0.27	2.09
	$T_1 - T_3$	0.03	0.39	> 0.999	-1.13	1.19
	$T_1 - T_4$	-2.24	0.45	0.001	-3.60	-0.88
	$T_2 - T_3$	-1.15	0.33	0.019	-2.14	-0.15
	$T_2 - T_4$	-3.41	0.58	< 0.001	-5.16	-1.67
	$T_3 - T_4$	-2.27	0.58	0.008	-4.02	-0.51
lm/Lop-pg/Lop	$T_1 - T_2$	-1.35	0.41	0.026	-2.58	-0.12
	$T_1 - T_3$	-1.62	0.53	0.045	-3.21	-0.03
	$T_1 - T_4$	-1.53	0.62	0.156	-3.41	0.35
	$T_2 - T_3$	-0.27	0.26	> 0.999	-1.05	0.52
	$T_2 - T_4$	-0.18	0.47	> 0.999	-1.59	1.24
	$T_3 - T_4$	0.09	0.35	> 0.999	-0.97	1.15

DISCUSSION

All patients that comprised this study presented, in T_1 , typical characteristics of Class II division 1 malocclusion, as confirmed by the initial cephalometric variables that describe the molar relationship (um/Lop - lm/Lop: 1.59 ± 1.61 mm) and the overjet (ui/Lop - li/Lop: 9.15 ± 2.74 mm). According to the inclusion criteria, all patients clinically presented mandibular retrognathism and accepted treatment that included mandibular advancement.

The results yielded by the present study are in agreement with previous studies that used similar methods.^{9,12,23,27} Both the maxilla (SS/Lop) and mandible (PPg/Lop) were anteriorly projected, but since mandibular growth increment was 3.5 times greater, there was a favorable sagittal maxillomandibular adjustment. In order to identify the contribution of mandibular growth, measurements of the absolute mandibular length (pg/Lop+co/Lop and pg/Lop+ar/Lop) were assessed and significant growth increment was observed, although the condylar (co/Lop) and articular (ar/Lop) points did not present any alterations.

The registered amount of skeletal growth allowed better a understanding of how the teeth varied in their sagittal spatial position. Overcorrection of the observed molar relationship (um/Lop-lm/Lop: 5.71 mm) was due to the association between maintenance of upper molars position (um/Lop: -0.09) while the maxilla was anteriorly projected (SS/Lop: -1.27 mm), and mesialization of lower molars (lm/Lop: -5.79 mm) along with mandibular anterior projection (pg/Lop: -4.44 mm). Overjet was significantly reduced from 9.5 mm to 2.65 mm, as a result of mandibular anterior projection (pg/Lop: -4.44 mm) and buccal inclination of lower incisors in their bone base (li/Lop: -6.21 mm). The mechanical effect observed in the inclination of lower incisors restricts the recommendation of this type of therapy to individuals who do not present increased inclination at treatment onset.

The occlusal plane (SN.LO), which in the beginning presented a mean value that is typical of a mesofacial pattern ($32.59 \pm 5.42^\circ$), was rotated clockwise (2.85°) by the presence of interocclusal acrylic splints. This might have caused the effect of molar intrusion, since, when the appliance was removed, an important posterior disocclusion was observed in all patients. This speculation can be done because, differently from the occlusal plane,

the inclination of the mandibular plane (SN.PM) did not undergo any alterations, thus confirming that it was just a dentoalveolar effect and not a skeletal one, therefore, the facial type did not change.

In the following 13 months after the Herbst appliance had been removed, which corresponded to orthodontic treatment onset (T_2 - T_3), the maxilla continued to be anteriorly projected (ss/Lop: -1.21 mm), whereas mandibular projection was little significant (pg/Lop: -1 mm). It was observed that partial recurrence of molar relationship (um/Lop-lm/Lop: -1.09 mm) occurred as a result of mesialization of upper molars (um/Lop-ss/Lop: -1.15 mm) along with non-significant mesialization of lower molars (lm/Lop-pg/Lop: -0.27). However, considering that a relation of overcorrection of molar relationship was observed in T_2 (um/Lop-lm/Lop: -4.12 mm), this recurrence was favorable to adjust the molars in Class I relation (um/Lop-lm/Lop: -3.03 mm). Additionally, there was a partial recurrence of 1.53 mm in overjet (ui/Lop-li/Lop) as a result of differential growth of the maxilla, which led the upper incisors to occupy a more anterior spatial position (is/Lop: -1.68 mm). This could not have been due to the insignificant uprighting of lower incisors (li/Lop: -0.15 mm) because, in this case, they did not change their position (li/Lop-pg/Lop: 0.85 mm).

The occlusal plane (SL.LO) rotated counterclockwise, since, from T_2 to T_3 , with the removal of the Herbst appliance, the molars were free from the interocclusal splints and, additionally, were actively leveled to the orthodontic appliance, restoring the vertical spatial position that they presented at treatment onset. These data corroborate data found in the literature,^{9,10} thus confirming that this movement happened without affecting the inclination of the mandibular plane (SN.PM), therefore, with preservation of facial type.

The complementary assessment carried out in this study, between the thirteen-month interval after removal of the Herbst appliance and the end of the active orthodontic treatment (T_3 - T_4), showed that, while the maxilla was not significantly anteriorly projected (SS/Lop: -0.53 mm), the mandible resumed its growth (pg/Lop: -3.09 mm), significantly anteriorly projecting itself. Molar relationship (um/Lop-lm/Lop: 0.21 mm) remained stable in Class I. Moreover, no expressive changes were observed for the overjet (ui/Lop-li/Lop: 0.44mm).

Nevertheless, when analyzing the maintenance of dental stability, during a period in which there was significant expression of mandibular growth and absence of significant maxillary growth, it could be observed that tooth movement was compensatory, maintaining both molar and overjet relations. While the upper incisors (ui/Lop: -1.65 mm) and the upper molars (um/Lop: -2.79 mm) were anteriorly projected in the absence of significant maxillary growth (ss/Lop: -0.53 mm), the lower incisors (li/Lop: -2.09 mm) and lower molars (lm/Lop: -3 mm) were also spatially anteriorly projected, however, in association with significant mandibular growth (pg/Lop: -3.09 mm). Thus, it can be concluded by means of the differential calculus (dental movement minus skeletal movement) that only the upper molars had a significant movement of mesialization, regardless of the growth of its bone base (um/Lop-ss/Lop: -2.27 mm). This movement was necessary to maintain Class I molar relationship. The occlusal plane remained stable (SN.LO: 1.74°). This fact can be explained because in T_3 , the molars already presented interocclusal contact and there were no additional vertical movements until T_4 . The mandibular plane remained unchanged, revealing a uniform behavior during the entire treatment, thus, preserving facial type.

When considering the series of changes observed from the beginning to the end of treatment (T_1 - T_4), it is verified that out of the total of maxillary anterior projection (3 mm), 42% happened during the orthopedic phase (T_1 - T_2) and 58% during the orthodontic phase (T_2 - T_4), of which the most part (40.3%) happened during the first 13 months (T_2 - T_3) and the rest (17.7%), an insignificant increase, between T_3 and T_4 . As shown in Tables 1 to 3, the mandibular anterior displacements (Pg/Lop) were compatible to the corresponding increment of the mandibular absolute growth (Pg/Lop+ar/Lop and Pg/Lop+co/Lop). When analyzing the variable Pg/Lop+co/Lop, it is verified that 48.2% of mandibular growth happened during the 13 months of the orthopedic phase (T_1 - T_2) as a response to the stimulus provided by the Herbst appliance, in a period when the potential growth was intense; whereas 51.8% happened during the orthodontic phase (T_2 - T_4). However, it must be emphasized that during the 13 months after the Herbst appliance was removed (T_2 - T_3), there was growth deceleration, with slight, non-significant growth increment (15.1%) and, therefore, without anterior projec-

tion. Significant growth was soon resumed, expressing the remaining 36.7% in the following months until T_4 . This type of response agrees with previous studies.^{4,9} It was very important to assess the amount of growth during the orthodontic phase (T_2 - T_4) as proposed in this study. Moreover, dividing observation into two periods, T_2 - T_3 (13 months) and T_3 - T_4 (33 months), was important to understand whether or not the curve of mandibular growth could modify its usual course before the stimulus given by the use of the Herbst appliance. Franchi et al²⁸ claim that mandibular growth follows the physical growth spurt and it is characterized by a gradual increase in the amount of increments until it reaches its maximum, when the greatest amount of growth is expressed. Afterwards, it gradually decelerates again, however, linearly, until growth is complete. In the present study, it was observed that during the 13 months of stimulus (T_1 - T_2) provided by the Herbst appliance, the increments were intense. Nevertheless, a deceleration in the following 13 months (T_2 - T_3), and then, a resumption of growth (T_3 - T_4), explain that the growth verified between T_1 and T_2 represents the favorable expression of the present growth potential, for being in its maximum (as revealed by the hand-wrist radiograph in T_1), which is summed up to the anticipation of growth in the subsequent 13 months, which, without the use of the appliance, would not have manifested at that moment, thus, modifying the behavior of the descendant curve of growth spurt in adolescence.

As for growth complexity and mandibular spatial projection in the face, our results can be explained by those observed by Pancherz et al²⁹ who assessed the "effective condylar growth" and its influence over the spatial position of the symphysis in the face. Their findings reveal that condylar growth triplicated during the active phase of six months in which the Herbst appliance was used, decelerated in a similar period after the removal of the appliance, and soon resumed its normal growth in the subsequent 30 months. Comparison between total mandibular and maxillary projection, from T_1 to T_4 , revealed that the mandible (pg/Lop: 8.47 mm) was projected 2.8 times more than the maxilla (ss/Lop: 3 mm), a fact that favored sagittal maxilomandibular adjustment.

With regard to dentoalveolar correction of Class II malocclusion, a favorable response was observed between T_1 and T_4 , i.e., Class II molar relationship and the

increase in overjet that patients presented at treatment onset were ideally corrected. In T_4 , all of them showed characteristics of normal occlusion, with good molar relationship and adequate overjet, thus, achieving the purpose of the treatment. In order to produce such results, treatment evolved from sagittal overcorrection of molar relationship, which was associated with great reduction in overjet during the 13-month orthopedic phase; partially relapsed at the beginning of the orthodontic phase and became stable in the following 33 months until the end of the treatment.

Based on the aforementioned observations, it is important to emphasize that: First, the recurrence of the overcorrected molar relationship between T_2 and T_3 was necessary for molars to obtain cusp-to-fossa relationship instead of cusp-to-cusp, which probably contributed to offer the stability observed in the subsequent period. Additionally, despite being significant, the degree of overjet relapse registered between T_2 and T_3 , did not prevent the values from being within the clinical parameters of normality by the end of the treatment. The second aspect is with regard to the stability observed in T_3 and T_4 , a period of 33 months. The advantage of lasting nearly two times longer than each previous period allowed the stability of results to be assessed.

Clockwise rotation of the occlusal plane was significant during the orthopedic phase (T_1 - T_2) and it happened as a result of the presence of interocclusal splints. In the subsequent phase (T_2 - T_3), it rotated counterclockwise, therefore, relapsing by the removal of the splints and active orthodontic leveling, thus, restoring intermaxillary occlusal contacts. This pattern of counterclockwise rotation continued in the following 33 months, however, insignificantly. As for the changes that occurred in opposite directions, the comparison between orthopedic and orthodontic phases reveal that they did not present any adverse clinical effect, since the

changes occurred without influencing the inclination of the mandibular plane. On the other hand, the occlusal plane restored its initial inclination in T_3 and remained stable until T_4 . The mandibular plane (SN.PM), which defines the facial type, was maintained in all periods of assessment, a fact that is favorable to the stability achieved in the long term, all of which agreed with other authors in the literature.^{9,30}

The size of the sample is a limitation of this study. However, it is of great value considering that it is a prospective study carried out with consecutive patients and that had never been performed with Brazilian patients. The results obtained from assessing these patients by means of the treatment protocol allowed us to visualize not only that the therapy applied was efficient, but also that the series of skeletal and dental changes observed did not cause a temporary impact, but an impact that is compatible with the conditions of stability in the long term. However, further studies are necessary to longitudinally assess the post-treatment phase. Finally, it is important to emphasize the undesirable effect that the use of the Herbst appliance can cause to individuals with increased buccal inclination of the lower incisors at treatment onset.

CONCLUSIONS

Based on the results of treatment of adolescents with Class II malocclusion and mandibular retrognathism performed in two phases (Herbst and pre-adjusted orthodontic appliance) it is reasonable to conclude that both skeletal and dental changes, when performed together, allowed the correction of the malocclusion. The mandible grew significantly more than the maxilla, which favored sagittal maxillomandibular adjustment. The dental changes (distalization of upper molars) that overcorrected the malocclusion in phase I partially relapsed in phase II, without compromising the correction of the malocclusion. The facial type was preserved.

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Prevalence of dental anomalies of number in different subphenotypes of isolated cleft palate

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Objective: This study aimed at carrying out a radiographic analysis on the prevalence of dental anomalies of number (agenesis and supernumerary teeth) in permanent dentition, in different subphenotypes of isolated cleft palate pre-adolescent patients.

Methods: Panoramic radiographs of 300 patients aged between 9 and 12 years, with cleft palate and enrolled in a single treatment center, were retrospectively analyzed. The sample was divided into two groups according to the extension/severity of the cleft palate: complete and incomplete. The chi-square test was used for intergroup comparison regarding the prevalence of the investigated dental anomalies ($P < 0.05$).

Results: Agenesis was found in 34.14% of patients with complete cleft palate and in 30.27% of patients with incomplete cleft palate. Supernumerary teeth were found in 2.43% of patients with complete cleft palate and in 0.91% of patients with incomplete cleft palate. No statistically significant difference was found between groups with regard to the prevalence of agenesis and supernumerary teeth. There was no difference in cleft prevalence between genders within each study group.

Conclusion: The prevalence of dental anomalies of number in pre-adolescents with cleft palate was higher than that reported for the general population. The severity of cleft palate did not seem to be associated with the prevalence of dental anomalies of number.

Keywords: Cleft palate. Tooth abnormalities. Panoramic radiograph.

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INTRODUCTION

The embryonic explanation for isolated cleft palate is the lack of fusion of the palatal shelves that form the secondary palate. In this type of cleft, the palatine processes do not fuse neither in the midline nor with the nasal septum, keeping the communication between oral and nasal cavities, while the formation of lips and alveolar ridge is processed normally.¹

Isolated cleft palate may be complete or incomplete.¹ It is considered complete when it affects the hard and soft palate, extending to the incisive foramen (Fig 1A). On the other hand, it is considered incomplete when it partially affects the soft and/or hard palate, not reaching the incisive foramen (Figs 1B, 1C and 1D).

The prevalence of cleft lip and palate is approximately 1:1000 births.¹ In general, individuals of Asian descent have higher prevalence while those of African descent have lower prevalence when compared to Caucasian individuals.² The etiology of cleft lip and palate is complex, with multifactorial causality, in which case both genetic and environmental factors play a major role in determining the malformation.³ From an embryological standpoint, cleft palate is a disorder that differs from cleft lip and palate. Differences in epidemiology and etiologic factors have also been reported in the literature.³

Similarly to the general population, odontogenic disorders are also found in patients with clefts. It is assumed that cleft and dental anomalies present a common or inter-related genetic origin, considering the high prevalence of dental anomalies in cleft patients.⁴ In other words, patients with clefts present more incidence of dental anomalies than individuals without clefts.⁵ Moreover, the prevalence of dental anomalies seems to be related to the extension/severity of cleft lip and palate.⁶

The diagnosis of dental anomalies of number is essential to define the treatment plan in the rehabilitation process of patients with cleft palate, either orthodontic, with prosthesis or implants. The purpose of this study was to radiographically assess the prevalence of dental anomalies of number in different subphenotypes of isolated cleft palate.

MATERIAL AND METHODS

This study was conducted in the department of Orthodontics at the Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo (HRAC-USP), after approval by the respective Institutional Review Board. The study analyzed the radiographs of 300 patients from the HRAC-USP files. The sample comprised 117 (39%) males and 183 (61%) females who were in late mixed dentition (second transitional period of mixed dentition according to the Van der Linden classification) and early permanent dentition. The patients aged between 9 and 12 years old (chronological age). At this age, the third molars were excluded from the evaluation.

The total sample was divided into two study groups, according to the extension of cleft palate indicated in the medical records of patients: Group 1 - complete cleft palate; and Group 2 - incomplete cleft palate.

The occurrence of permanent teeth agenesis and supernumerary permanent teeth was evaluated in panoramic radiographs by a calibrated observer with the aid of a film viewer in a room with appropriate lightening. The study included only radiographs with good technical quality that allowed good visualization of teeth, erupted or not, and their surrounding structures.

After the prevalence of dental anomalies was calculated in each study group, the chi-square test was used for comparison. It was also used to verify intragroup differences in the prevalence of anomalies between sexes. The results were considered at a significance level of 5%.

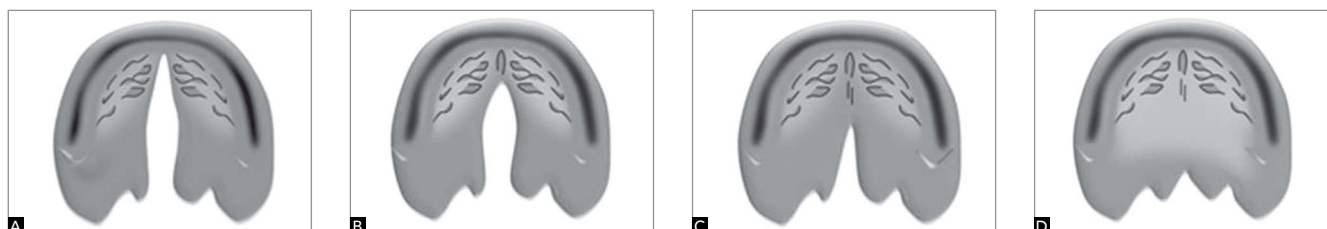


Figure 1 - Complete cleft palate invariably extends from the incisive foramen to the uvula (A). Incomplete cleft palate involves the posterior region of the palate without reaching the incisive foramen (B); affects the soft palate and part of the hard palate (C); or may affect only the soft palate (D).

RESULTS

Out of the 300 patients analyzed, 82 (27.33%) had complete cleft palate, whereas 218 (72.66%) had incomplete cleft palate. Among individuals with complete cleft palate, 31 (37.8%) were males and 51 (62.19%) females. As for patients with incomplete cleft palate, 86 (39.44%) were males and 132 (60.55%) females. In both groups, the proportion between male and female was approximately 1:2.

The prevalence of dental anomalies in Group 1 (complete cleft palate) and Group 2 (incomplete cleft palate) is expressed in percentage and presented in Table 1. In Group 1, tooth agenesis of permanent teeth excluding the third molars was observed in 28 (34.14%) patients, while supernumerary teeth were found in 2 (2.43%). In Group 2, tooth agenesis was observed in 66 (30.27%) patients, while supernumerary teeth was found in 2 (0.91%). No significant difference in the prevalence of hypodontia

and supernumerary teeth was found between Groups 1 and 2 (Table 1). Additionally, there was no difference between groups in the prevalence of agenesis for the most commonly affected teeth: second premolars and maxillary lateral incisors (Table 1).

Figures 2 and 3 show the prevalence of agenesis of each permanent tooth in Groups 1 and 2, respectively. With regard to supernumerary teeth, in Group 1 they were found in the region of the maxillary left lateral incisor and the maxillary left second premolar, while in Group 2 supernumerary teeth were observed in the region of the maxillary right lateral incisor and between the central incisors (mesiodens).

The distribution of dental anomalies according to sex is shown in Table 2. In both groups, there was no statistically significant difference between males and females for the prevalence of tooth agenesis and supernumerary teeth (Table 2).

Table 1 - Prevalence of dental anomalies in groups 1 and 2, and intergroup comparison results (chi-square test).

	G1 + G2	G1	G2	χ^2	p
Hypodontia	31.33%	34.14%	30.27%	0.0064	0.9359
Supernumerary	1.33%	2.43%	0.91%	0.0000	1.0000
Hypodontia MxLI	8.50%	7.92%	8.71%	1.9340	0.1644
Hypodontia Mx2P	7.50%	9.14%	6.88%	0.0000	1.0000
Hypodontia Md2P	8.66%	6.70%	9.40%	0.2545	0.6139

* MxLI = maxillary lateral incisor, Mx2P = maxillary second premolar, Md2P = mandibular second premolar.

Table 2 - Prevalence of dental anomalies according to sex and intragroup comparison results (chi-square test).

	Complete cleft palate				Incomplete cleft palate			
	Female	Male	χ^2	p	Female	Male	χ^2	p
Hypodontia	35.29%	32.25%	0.0390	0.8434	32.57%	26.74%	0.2798	0.5968
Supernumerary	0%	6.45%	1.0960	0.2952	0%	2.32%	1.0300	0.3101

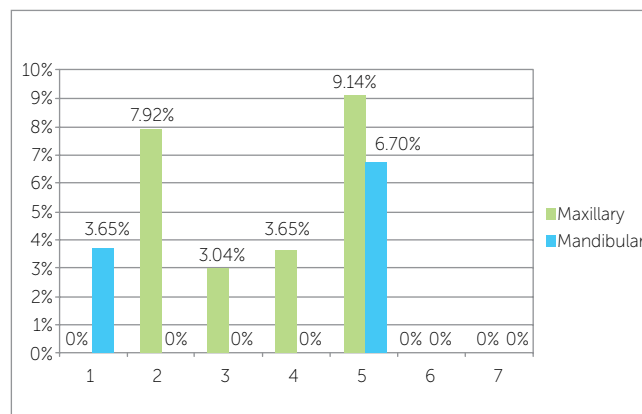


Figure 2 - Prevalence of agenesis of each permanent tooth (excluding third molars) in the complete cleft palate group (group 1).

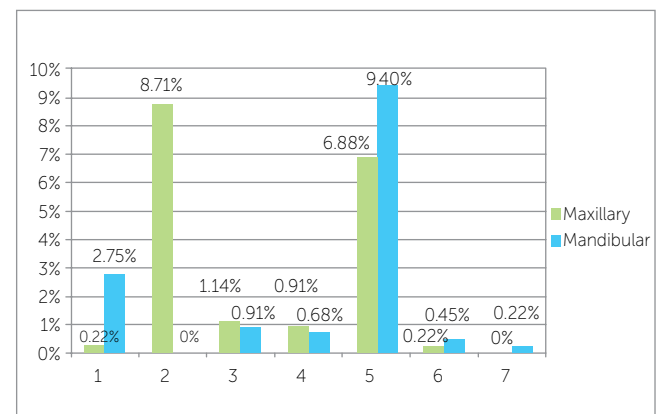


Figure 3 - Prevalence of agenesis of each permanent tooth (excluding third molars) in the incomplete cleft palate group (group 2).

DISCUSSION

Cleft palate is more common among female patients.^{1,7} In this study, both complete and incomplete cleft palate prevailed in females. In individuals without clefts, excluding the third molars, the prevalence of tooth agenesis in the population varies from 4.3% to 7.8%, primarily affecting the mandibular second premolar, followed by the maxillary lateral incisor and maxillary second premolar.⁸ The present results show that the prevalence of tooth agenesis is much higher in individuals with cleft palate than in the general population.

According to this study, the prevalence of hypodontia of permanent teeth, excluding the third molars, in patients with cleft palate was 31.33% and was similar to that reported in the literature for patients with these malformations. Previous studies reported a prevalence of permanent tooth agenesis in patients with cleft lip and palate of 25.5% to 33% in Czech patients,⁹ 30% in Swedish patients,¹⁰ 25% to 40%¹¹ and 33% in Finnish patients¹² and 28.5% in Norwegian patients.¹³ Another previous study reported that tooth agenesis was observed more frequently in patients with complete cleft palate than in patients with incomplete cleft palate.¹¹ However, our study did not find any difference in the occurrence of hypodontia according to the subphenotypes (Table 1).

As for the subphenotypes, in both complete and incomplete cleft palate the teeth most affected by hypodontia were the maxillary and mandibular second premolars as well as maxillary lateral incisors, particularly the maxillary second premolars in complete cleft palate and the mandibular second premolars in incomplete cleft palate (Figs 2 and 3). These data are in accordance with other reports in the literature,^{9,10,14} and are similar to those found for the general population.⁴

The prevalence of supernumerary teeth in patients with cleft palate found in our study is similar to the prevalence found for the general population, with no significant difference between complete and incomplete

cleft subphenotypes. Supernumerary teeth were prevalent in 2.43% of group 1 and 0.91% of group 2 (Table 1). In patients with complete palatine cleft, supernumerary teeth were found in the region of maxillary left lateral incisors and maxillary left second premolars. In patients with incomplete cleft palate, they were found in the region of maxillary right lateral incisors and between the central incisors (mesiodens). The prevalence of supernumerary teeth in adolescents without clefts is 1% to 2%.¹⁵ A previous investigation found no supernumerary teeth in patients with isolated cleft palate.¹⁰

A recent study found that the presence of dental anomalies may represent an additional clinical marker for oral clefts, suggesting a common genetic origin for these anomalies.¹⁶ The development of tooth germs and the occurrence of cleft palate are closely related during embryological development, both anatomically and chronologically, and many studies have reported the manifestation of dental anomalies associated with various forms of cleft lip, cleft palate or both.¹⁶ It has been proposed that individuals with cleft have higher prevalence of dental anomalies than the general population, and that the severity of the malformations seems to be directly related to the extension of the cleft.¹⁶ In this study, the prevalence of tooth agenesis and the total prevalence of dental anomalies, except for supernumerary teeth, was slightly higher in female patients, although no statistically significant difference was found. The same was observed for the occurrence of complete and incomplete isolated cleft palate.

CONCLUSION

The prevalence of dental anomalies of number seems not to be related to the subphenotypes of cleft palate. Individuals with complete and incomplete cleft palate showed a similar prevalence of permanent tooth agenesis and supernumerary teeth. Further studies are necessary to determine the exact inter-relation between cleft palate and the prevalence of other dental anomalies.

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Are self-ligating brackets related to less formation of *Streptococcus mutans* colonies? A systematic review

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Objective: To verify, by means of a systematic review, whether the design of brackets (conventional or self-ligating) influences adhesion and formation of *Streptococcus mutans* colonies.

Methods: Search strategy: four databases (Cochrane Central Register of Controlled Trials, Ovid ALL EMB Reviews, PubMed and BIREME) were selected to search relevant articles covering the period from January 1965 to December 2012. Selection Criteria: in first consensus by reading the title and abstract. The full text was obtained from publications that met the inclusion criteria. Data collection and analysis: Two reviewers independently extracted data using the keywords: conventional, self-ligating, biofilm, *Streptococcus mutans*, and systematic review; and independently evaluated the quality of the studies. In case of divergence, the technique of consensus was adopted.

Results: The search strategy resulted in 1,401 articles. The classification of scientific relevance revealed the high quality of the 6 eligible articles of which outcomes were not unanimous in reporting not only the influence of the design of the brackets (conventional or self-ligating) over adhesion and formation of colonies of *Streptococcus mutans*, but also that other factors such as the quality of the bracket type, the level of individual oral hygiene, bonding and age may have greater influence. Statistical analysis was not feasible because of the heterogeneous methodological design.

Conclusions: Within the limitations of this study, it was concluded that there is no evidence for a possible influence of the design of the brackets (conventional or self-ligating) over colony formation and adhesion of *Streptococcus mutans*.

Keywords: Biofilms. Orthodontic brackets. *Streptococcus mutans*. Review.

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INTRODUCTION

Increased oral microbiota of *Streptococcus mutans* and *Lactobacillus* is associated with the onset of tooth demineralization and periodontal disease, especially in orthodontic patients who present greater risk of colonization by these microorganisms.¹⁻⁴ It seems that the main factor behind the increase in the accumulation of dental plaque and inflammatory response is the appearance of new locations of retention around the components of fixed orthodontic appliance.⁵ The devices used in orthodontic appliances (bands, wires, ligatures or brackets) can promote changes in the oral environment, such as pH, amount of *Streptococcus mutans*, biofilm⁶⁻⁹ and enamel decalcification.¹⁰⁻¹⁶ The clinical characteristics and the physical properties of the bracket types are very different,¹⁷ and, thus, can directly influence the amount of biofilm adhesion and, consequently, gingivitis.^{5,18-22} The characteristics of both the surface of the teeth and the gingiva influence the spontaneous formation of plaque, not only in quantity, but also in quality.^{18,23-30} Saliva composition and secretion rate also influence plaque formation.²⁷

Conventional brackets (C) are associated with the use of either elastomeric or stainless steel ligature to keep the orthodontic wire inside the slot.⁸ In Orthodontics, the term self-ligating (SL) refers to orthodontic brackets that have their own mechanism for opening and closing the slot, and do not require any metal or elastomeric ligature as a method for wire ligation.^{31,32} All these methods have advantages and disadvantages, but in relation to biofilm retention, the literature^{8,33} suggests that it is greater with elastomeric ligatures. Orthodontic treatment with C brackets usually presents some periodontal changes as side effects caused by difficulty in periodontal hygiene and also by greater accumulation and qualitative alteration of plaque.^{3,5,6,8,19,20} Thus, in order to improve the deficiency of conventional brackets systems, SL were developed so as to, according to the manufacturers and some studies,^{8,34-38} allow better hygiene. They claim that SL brackets are less susceptible to bacterial colonization due to their shape and absence of elastomeric and metal ligatures.³³ It is questionable, however, if the adhesion of microorganisms and the development of biofilm is reduced by the removal of ligatures of conventional brackets and with the use of the opening and closing mechanism of SL systems. Even with the changes in modern bracket types, the problem of plaque accumulation around the brackets is still persistent in daily orthodontic practice.^{37,39}

Over the years, many publications^{6-11,33,34,38-41} have reported different results concerning microorganism adhesion and biofilm development for C and SL brackets. Biofilm adhesion on brackets is measured by different systems, which hinders the evaluation of scientific quality. Therefore, it was proposed to verify, through a systematic review, whether bracket design (conventional or self-ligating) influences adhesion and formation of *Streptococcus mutans* colonies. Additionally, the methodological soundness of the studies included in the review was assessed in terms of quality.

MATERIAL AND METHODS

Search strategy

The strategy of this review was based on the National Health Service Center for Reviews and Dissemination.⁴² Four databases (Cochrane Central Register of Controlled Trials; Ovid ALL EMB Reviews, PubMed and Bireme) were selected to find relevant articles published between January 1965 and December 2012. The search used the keywords “conventional” and/or “self-ligating” crossed with combinations of the terms biofilm and / or *Streptococcus mutans* and / or systematic review. Two reviewers separately sought additional relevant publications, which may not have been in the searched databases, by manually searching for papers in libraries and contacting authors. There were no language restrictions. As a first step, the reviewers selected the articles by reading titles and abstracts. Full texts were obtained from publications that met the inclusion criteria. After the articles were selected, their scientific relevance was independently assessed by the reviewers, and in case of divergence, the technique of consensus was adopted. This review used the PICO (Population Intervention Comparator Outcomes) strategy⁴³ to develop both the research and the bibliography (Table 1).

Inclusion and exclusion criteria

The inclusion criteria for the selected studies initially aimed at human beings, only: those who were periodontally healthy before the study began and who were at 11 years of age or older. The randomized and controlled clinical trials had to involve conventional edgewise and/or self-ligating brackets prescriptions. Case reports, review articles, abstracts and letters to the Editor were also included. The exclusion criteria comprised studies carried out with animals, *in vitro*

Table 1 - Description of the PICO (Population Intervention Comparator Outcomes) strategy used to develop the research and the bibliography.

Acronym	Description
Population	Patients with fixed orthodontic appliance with conventional or self-ligating edgewise brackets.
Intervention	Assessment of the amount of biofilm and microbiota attached to conventional or self-ligating brackets.
Comparison	Through the levels of biofilm accumulation on conventional or self-ligating brackets.
Outcomes	Measurement of colonies of <i>Streptococcus mutans</i> and/or their effects on periodontal tissues.

studies, treatment plans that included extractions of premolars as well as studies that included patients younger than 11 years of age, with periodontal problems, who were users of antibiotics and oral antiseptic solutions, alcoholics and smokers. Articles mentioning patients who used mechanical and anchoring devices, as well as Hyrax, were also excluded.

Assessment of the scientific relevance of the eligible studies

The following data were collected from each one of the papers selected: author/year of publication, journal, study design, age, teeth involved, bracket type and brand, ligature type, objective and method of analysis, follow-up, statistical analysis and outcome. A quality assessment⁴⁴ was performed on each article, according to the following ten criteria:

- 1) Study design (randomized clinical trials [RCT], prospective [P] or controlled clinical trials [CCT]) = 2 points.
- 2) Adequate study description = 1 point.
- 3) Adequate sample size = 1 point.
- 4) Adequate sample selection description = 1 point.
- 5) Drop outs description = 1 point.
- 6) Adequate description of biofilm measurement method = 0.5 point.
- 7) Blind study = 0.5 point.
- 8) Adequate statistics = 1 point.
- 9) Confounding factors considered = 1 point; and
- 10) Clinical significance = 1 point.

The ten criteria specified above were used to identify the scientific relevance of the methodological quality of the reviewed papers. The rating was “low” when the points given were less than or equal to 4, “medium” from 5 to 8 points and “high” for 9 or 10 points.

RESULTS

Search strategy outcomes

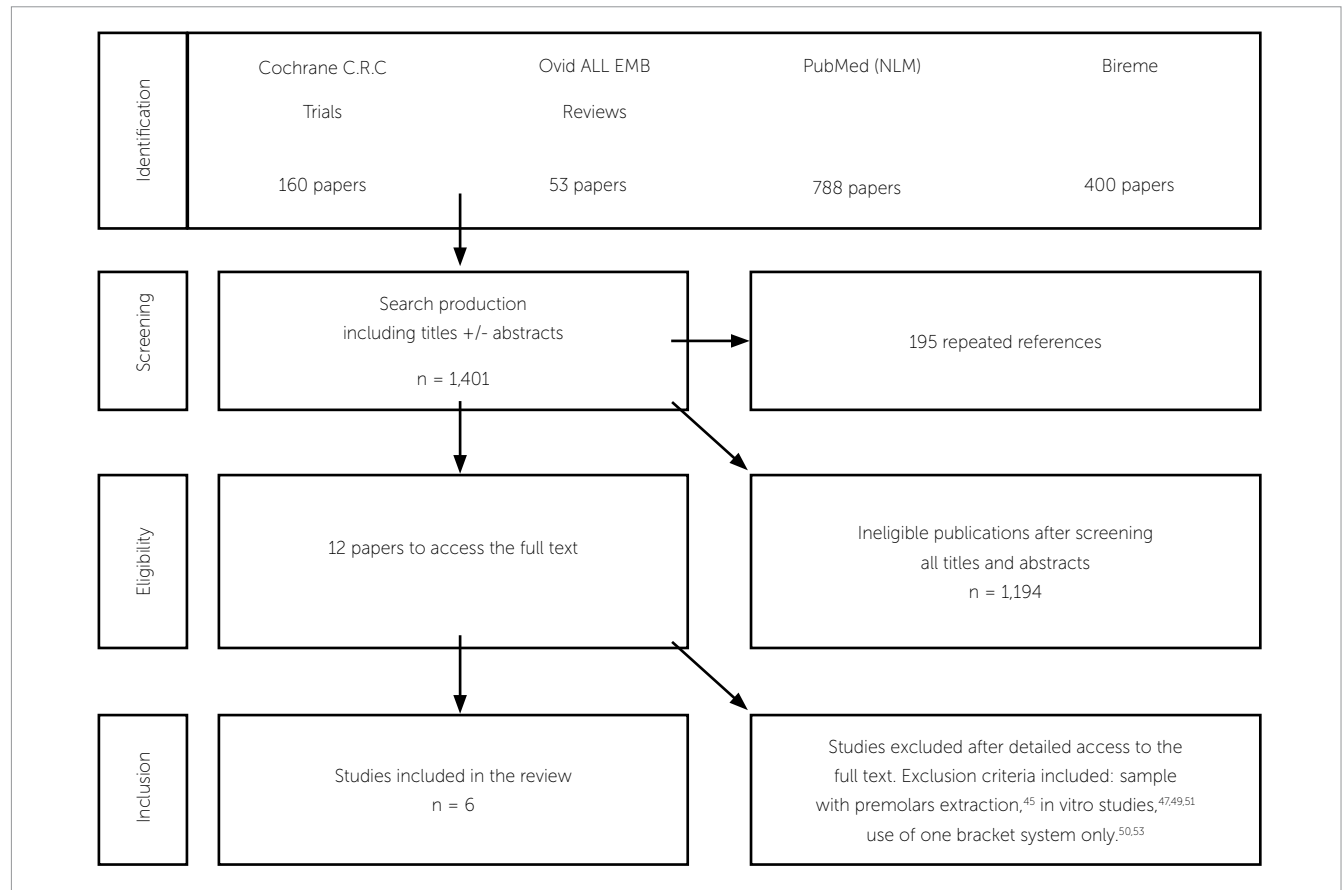
The search strategy resulted in 1,401 articles, out of which 195 were repeated references. The exclusion criteria used by both independent reviewers excluded 1,194 articles, which were not considered as relevant to the review, thus, totalizing twelve potentially relevant articles.^{33,45-55} They were chosen for retrieval and evaluation of the full text, for which a summarized data extraction sheet was used (Table 2). Out of the twelve full-text articles that were retrieved, 6 were excluded because: one article⁴⁵ presented premolar extractions in its sample, three^{47,49,51} were *in vitro* studies, and two^{50,53} did not provide a direct comparison between C and SL brackets systems. This resulted in six articles^{33,46,48,52,54,55} that were suitable for the final analysis as they evaluated periodontal and clinical variables originating from bacterial adhesion in patients with C and SL brackets (Fig 1).

Assessment of the scientific relevance of the eligible studies

The six articles^{33,46,48,52,54,55} included in this review (Table 3) met the inclusion criteria, although with differences among their methods of study, sampling, analysis and follow-up. All the eligible studies^{33,46,48,52,54,55} compared both systems: conventional and self-ligating edgewise brackets. Pandis⁴⁶ also made reference to gingival plaque and calculus index, whereas the article by van Gastel⁴⁸ examined the amount of gingival fluid and anaerobic and aerobic colonies. Another study carried out by Pandis⁵⁴ collected saliva 2-3 months after orthodontic appliances had been bonded. *Mitis salivarius* culture medium (MS), specific for *Streptococcus mutans*, was used to count the colony forming units (CFU). Pithon⁵² collected the plaque samples directly from SL and C brackets of different brands, and 3

Table 2 - Search data, search strategies and number of results for each database.

Database	Search strategies	Results	Selected papers
Cochrane C.R.C. Trials	conventional OR self-ligating	160	2
Ovid ALL EMB Reviews	exp Orthodontic Appliances / OR edgewise.mp. AND exp Orthodontic Appliance Design/ OR exp Orthodontic Brackets/ OR self-ligating.mp. OR exp Orthodontic Appliances/ AND biofilm.mp. OR exp Dental Biofilm Index/ AND streptococcus mutans.mp. OR exp Streptococcus mutans/	53	4
PubMed (NLM)	conventional AND self-ligating, OR biofilm OR Streptococcus mutans	788	5
Bireme	conventional OR self-ligating	400	1
TOTAL		1,401	12

**Figure 1** - Review flowchart.

weeks after bonding, the CFU was carried out in the following culture medium: MS, specific for *S. mutans*, and BHI (Brain Heart Infusion), not specific for bacteria and fungi. In this study,⁵² CFU was visually performed after 24, 48 and 72 hours of incubation. Pejda et al⁵⁴ collected the plaque samples of subgingival sulcus after 18 weeks of treatment, counting 5 periodontal pathogens by PCR, while Pellegrini et al³³ collected the samples from tooth surfaces surrounding the brackets after 5 weeks of bonding, and the CFU was analyzed by MS and bioluminescence of ATP (adenosine triphosphate).

When evaluating the scientific relevance of the six eligible articles,^{33,46,48,52,54,55} we found that the description of the sample selection was appropriate, however, the number of drop outs was declared in studies by Pellegrini,³³ Pandis,⁴⁶ van Gastel⁴⁸ and Pejda⁵⁴. All studies^{33,48,52,54} provided the approval of the Institutional Review Board, except for the articles by Pandis,^{46,55} who asked for the consent of patients / parents before starting the study, only. Considering the confounding factors, similar oral routine and hygiene instructions were given to the subjects taking part in these six studies.^{33,46,48,52,54,55}

Table 3 - Summarized data of the six studies included in the review.

Author Year Journal	Pellegrini et al ³³ 2009 AJODO	Pandis et al ⁴⁶ 2008 Orthod Craniofac Res	van Gastel et al ⁴⁸ 2007 Journal of Clinical Periodontology	Pithon et al ⁵² 2011 Braz J Oral Sci.	Pejda et al ⁵⁴ 2012 Angle Orthod	Pandis et al ⁵⁵ 2010 Eur J Orthod
Type of study	Randomized controlled trial	Prospective cohort	Randomized controlled trial	Randomized controlled trial	Randomized controlled trial	Randomized controlled trial
Number of patients	18	100	16	5	38	32
Age	11-17 y	12-17 y	17-27 y	20-30 y	11-18 y	11-17 y
Teeth involved	Lateral incisors	Maxilla and mandible	1 st and 2 nd premolars	Canines; 1 st and 2 nd premolars and molars (lower)	Maxilla and mandible	Maxilla and mandible
Bracket type/brand	14 p: C – Mini Ovation 14 p: SL – Innovation – R GAC	50 p: C – GAC 50 p: SL – In-Ovation – R – GAC	16 C – GAC 16 SL – Speed	10 C – Morelli 40 SL: GAC; Aditek; Ormco; 3M Unitek	19 p: C – Sprint Forestadent 19 p: SL – Damon 3MX, Ormco	16 p: C – GAC 16 p: SL – In-Ovation R – GAC
Ligature type	Elastomeric ligatures for the C brackets	Elastomeric ligatures for the C brackets	Elastomeric ligatures for the C brackets	Elastomeric ligatures for the C brackets	Metal ligatures for the C brackets	Elastomeric ligatures for the C brackets
Objective of analysis	Accumulation of bacterial plaque around the brackets. To determine if ATP by bioluminescence may be useful in assessing the plaque index	Index of gingival plaque and calculus of the pocket depth	Crevicular fluid and pocket depth. Aerobic (An) colonies	<i>S. mutans</i> and other microorganisms attachment to C and SL.	Accumulation of different microorganisms on C and SL.	Effect of the type of bracket (C or SL) on the levels of <i>S. mutans</i> in saliva
Method of analysis	MSB specific for <i>S. mutans</i> and determination by bioluminescence	Clinical periodontal parameters	Clinical and microbiological periodontal parameters	MSB specific for <i>S. mutans</i> and BHI, not specific for bacteria and fungus	Clinical periodontal parameters and PCR	MSB specific for <i>S. mutans</i>
Follow-up	5 w	18 m	7 d	21 d	18 w	2-3 m
Statistical analysis	T-tests (1-tailed, with $P < 0.05$). Chi-squared χ^2	χ^2 Wilcoxon Stata	ANOVA Tukey-Kramer	SPSS 13.0 Wilcoxon ($P < 0.05$)	T-tests Sidak post hoc Fisher's tests	ANOVA Minitab 14.20 χ^2
Outcome	SL favor reduced accumulation of <i>S. Mutans</i> and ATP by bioluminescence is useful in assessing plaque index	No advantages of SL over C with respect to the periodontal status of the mandibular anterior teeth	Bracket design can have a significant impact on bacterial load and on periodontal parameters	The hypothesis that self-ligating brackets favor greater aggregation of microorganisms was proved	Bracket design does not seem to have a strong influence on clinical parameters and periodontal pathogens in subgingival plaque.	The total levels of <i>S. mutans</i> do not seem to be significantly different between C and SL brackets

p = patients; y = years; m = months; w = weeks; d = days; h = hours; C = conventional brackets; SL = self-ligating brackets; *S.* = *Streptococcus*; SEM = scanning electron microscopy; ATP = adenosine triphosphate; MSB = Mitis Salivarius agar; BHI = brain heart infusion; PCR = polymerase chain reaction.

In the papers,^{46,54} full alignment of the mandibular arch was necessary to eliminate crowding as a confounding factor, but the clinical variables were assessed by the same periodontist. The examiner in the study carried out by Pandis⁴⁶ was not blinded, which could have influenced the outcome of the research, making the results biased. The study conducted by Pithon⁵² did not describe whether it had a blinded examiner, however, as a confounding factor, randomized participants were

asked whether they had already received any kind of orthodontic treatment with fixed appliances, since this can have consequences for the smoothness of the tooth enamel and for microbial adhesion at the beginning of biofilm formation.^{5,20,21} All six studies^{33,46,48,52,54,55} used appropriate statistical methods. The examiner's calibration level was reported in one single study,⁵⁴ and only two papers^{54,55} identified the sample calculation. Smoking or medical conditions were clearly identified in

studies by van Gastel,⁴⁸ Pejda⁵⁴ and Pandis.⁵⁵ As for the other studies,^{33,46,52} these conditions were declared only after the authors were requested to do so. The final score of the scientific relevance, in accordance with the Jadad scale,⁴⁴ was 10.0 for Pellegrini³³ and Pejda⁵⁴, 9.5 for van Gastel⁴⁸ and Pandis⁵⁵, and 9.0 for Pandis⁴⁶ and Pithon⁵² (Table 4), which revealed high-quality researches and methodological soundness.

Assessment of the eligible studies outcomes

Among the selected studies, four^{46,48,54,55} had their outcomes consistent in reporting that (a) SL brackets have no advantages over C in periodontal condition of anterior mandibular teeth;⁴⁶ (b) the design of the brackets can have significant impact on bacterial load and periodontal parameters;⁴⁸ and (c) in subgingival plaque and saliva, there seems to be no significant differences in the total levels of *S. Mutans* and periodontal pathogens between C and SL.^{54,55} However, a study⁵² confirmed the hypothesis that SL brackets favor the accumulation of micro-organisms, while another study³³ reported that SL brackets promote lower retention of *S. mutans* when compared to C (Table 3). The outcomes of the eligible studies^{33,46,48,52,54,55} were not unanimous in reporting that there is evidence of a possible influence of bracket design (conventional or self-ligating) over adhesion and formation of *Streptococcus mutans* colonies.

DISCUSSION

A systematic review can confirm the quality of a research as well as the methodological soundness of works selected from the literature. Additionally, it can present them for consideration of the clinical and scientific communities. Evidence-based practice requires the construction of a research question and a literature review.

Conventionally, to attach the wire to the brackets, three methods are used: metal ligature, elastomeric ligatures, and the open-close devices of SL brackets. All these methods have advantages and disadvantages, but with regard to the accumulation of biofilm, the literature^{8,33} suggests that elastomeric ligatures favor the retention of biofilm in comparison with the other two methods of ligatures. The question prepared for this review aimed to verify whether bracket design (conventional or self-ligating) influences the formation of *Streptococcus mutans* colonies. Micro-organisms exhibit significant adherence to brackets because there are favorable ecological niches in the porous (rough and irregular surfaces of these brackets).^{39,47,49,51,56} Thus, the characteristics of the bracket surface can be considered as harboring favorable sites for the adhesion of biofilm.

Search strategy outcomes

This research was highly sensitive, addressing evidence of minimum bias. The study carried out by

Table 4 - Quality assessment of the six retrieved studies.

	Pellegrini et al ³³ 2009 AJODO	Pandis et al ⁴⁶ 2008 Orthod Craniofac Res	van Gastel et al ⁴⁸ 2007 Journal of Clinical Periodontology	Pithon et al ⁵² 2011 Braz J Oral Sci.	Pejda et al ⁵⁴ 2012 Angle Orthod	Pandis et al ⁵⁵ 2010 Eur J Orthod
Type of study	2.0	2.0	2.0	2.0	2.0	2.0
Study description	1.0	1.0	1.0	1.0	1.0	1.0
Sample size	1.0	1.0	1.0	0.5	1.0	1.0
Sample selection description	1.0	1.0	1.0	1.0	1.0	1.0
Drop out description	1.0	0.5	0.5	1.0	1.0	0.5
Measurement method	0.5	0.5	0.5	0.5	0.5	0.5
Blind study	0.5	---	0.5	---	0.5	0.5
Statistics	1.0	1.0	1.0	1.0	1.0	1.0
Confounding factors	1.0	1.0	1.0	1.0	1.0	1.0
Clinical significance	1.0	1.0	1.0	1.0	1.0	1.0
Scale score (Jadad ⁴⁴)	10.0	9.0	9.5	9.0	10.0	9.5
Quality standard assessed	high	high	high	high	high	high

Jordan and LeBlanc⁵⁰ was excluded due to: (a) having assessed one bracket system only, (b) having a not blinded examiner and (c) presenting unspecified statistical analyses. The *in vitro* studies that were excluded^{47,49,51} did not have the inherent characteristics which contribute to the development of intra-oral biofilm, and may provide bias results for clinical periodontal conditions.²² The differences observed between the results of some papers^{33,46,48-50,52} may be related to factors that include: variations in the shape, material and size between SL and C brackets, the individual level of oral hygiene, salivary flow, treatment variables, types of ligatures, bonding procedures and age of the individuals involved.^{24,45,49,51,55} Thus, bracket type itself would not be a deciding factor for biofilm development, but its composition and material type should be included as factors behind *Streptococcus mutans* colonies formation.⁵⁶

Assessment of the scientific relevance of the eligible studies

The statistical analysis of our results was not feasible, given that the methodological designs of the eligible articles were heterogeneous. However, the scientific relevance assessment revealed high-quality researches and methodological soundness of all six studies,^{33,46,48,52,54,55} as shown in their final scores, according to the Jadad scale.⁴⁴

Although SL brackets do not require ligatures, their opening and closing mechanism may provide sites for biofilm adhesion similarly to conventional brackets.⁴⁶ This mechanism of SL brackets is not renewed, as it occurs with elastomeric modules in conventional brackets. Moreover, plaque calcification in SL leads to a malfunction of the opening and closing mechanisms. Thus, the theoretical advantages of self-ligating over conventional brackets can be eliminated, as confirmed by other studies.^{46,52} When using conventional brackets, neither the elastomeric rings nor the metal ligatures seem to affect the distribution of bacterial morphotypes in brackets or on the enamel surface.³ Aged elastomeric surfaces can apparently favor plaque retention in comparison with polished stainless steel ligatures, but there are no differences between periodontal conditions of patients treated with these two types of ligatures.^{8,57} Nevertheless, some studies^{41,58} report that brackets with elastomeric

rings favor damage to gingival conditions, with significant accumulation of biofilm, while the metal ligature had lower retention of biofilm in comparison with other brackets. Some reports^{59,60} affirm that C brackets are directly related to the retention of biofilm, however, the study conducted by Pithon et al⁵² suggests that cross-infection caused by replacement of elastomeric rings is controllable with the use of C brackets, because this type of brackets favors lower formation of *S. Mutans* colonies, which agrees with the study by van Gastel et al⁴⁸ that showed no difference between C and SL in gingival bleeding.

Assessment of the retrieved studies outcomes

The increase in oral microbiota attachment of *Streptococcus mutans* and *Lactobacillus* is associated with the use of orthodontic appliances,^{6,8,9,33,45} with both C or SL brackets. This increase leads to higher cariogenic plaque, pH low enough to change the clinical periodontal parameters^{46,48,54} and increased risk of enamel demineralization.^{6,47}

Some eligible studies^{52,54} evaluated not only the presence of *S. mutans*, but also of other microorganisms related to periodontal disease in patients with C or SL brackets. The study conducted by Pejda et al⁵⁴ found 23.8 times more chance of finding *Aggregatibacter actinomycetemcomitans* (AA) in subgingival plaque of patients with C brackets, but the increase in AA does not represent a risk factor for local periodontitis, as studies by Paolantonio et al^{61,62} confirm. The differences found between the results of the study by Pithon et al⁵² and the other studies assessed^{33,46,48,54,55} may have been due to methodological differences in some of these studies^{46,48,54,55} in which the CFU were counted from material collected from saliva; Pellegrini et al³³ collected it from tooth surfaces surrounding the bracket; and, in the study by Pithon,⁵² it was directly collected from the surface of brackets (winglets, slot and cervical region). That was the reason why this latest study should have found statistically significant differences that reveal greater accumulation of biofilm in SL brackets.

Clinical implications

Some studies^{8,33-39} report that SL brackets are less susceptible to bacterial colonization due to their shape and lack of metal or elastomeric ligatures. However, adequate control of biofilm is more strongly influenced by

the correct orientation and cooperation of patients^{24,55} than by simply choosing one system of brackets instead of another. The outcomes of the eligible studies^{33,46,48,52,54,55} were not unanimous in reporting a possible influence of bracket design (conventional or self-ligating) over the adhesion and formation of *Streptococcus mutans* colonies.

The decision of orthodontists on prescribing the use of SL instead of C in their clinical routine, aiming at improving hygiene / plaque accumulation, cannot yet be applied due to lack of scientific evidence.^{46,48,52,54,55} After this review, we presume that there is not enough evidence to support the use of fixed appliances with SL brackets in place of systems with C or vice versa, which agrees with the study by Fleming et al.⁶³

Based on the limitations of some works,^{64,66} further studies on other types of brackets, for example, esthetic self-ligating ones, must be performed to visualize the periodontal complications arising from different shapes, sizes and material types of brackets, and with that, guide the development of new systems of brackets design in order to reduce the formation of *Streptococcus mutans* colonies.

CONCLUSIONS

Within the limitations of this study, it was concluded that there is no evidence for a possible influence of bracket design (conventional or self-ligating) over colony formation and adhesion of *Streptococcus mutans*.

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Mechanical properties of NiTi and CuNiTi wires used in orthodontic treatment. Part 2: Microscopic surface appraisal and metallurgical characteristics

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Objective: This research aimed at comparing the qualitative chemical compositions and the surface morphology of fracture regions of eight types of Nickel (Ni) Titanium (Ti) conventional wires, superelastic and heat-activated (GAC, TP, Ormco, Masel, Morelli and Unitek), to the wires with addition of copper (CuNiTi 27°C and 35°C, Ormco) after traction test.

Methods: The analyses were performed in a scanning electronic microscope (JEOL, model JSM-5800 LV) with EDS system of microanalysis (energy dispersive spectroscopy).

Results: The results showed that NiTi wires presented Ni and Ti as the main elements of the alloy with minimum differences in their composition. The CuNiTi wires, however, presented Ni and Ti with a significant percentage of copper (Cu). As for surface morphology, the wires that presented the lowest wire-surface roughness were the superelastic ones by Masel and Morelli, while those that presented the greatest wire-surface roughness were the CuNiTi 27°C and 35°C ones by Ormco, due to presence of microcavity formed as a result of pulling out some particles, possibly of NiTi.⁴ The fracture surfaces presented characteristics of ductile fracture, with presence of microcavities. The superelastic wires by GAC and the CuNiTi 27°C and the heat-activated ones by Unitek presented the smallest microcavities and the lowest wire-surface roughness with regard to fracture, while the CuNiTi 35°C wires presented inadequate wire-surface roughness in the fracture region.

Conclusion: CuNiTi 35°C wires did not present better morphologic characteristics in comparison to the other wires with regard to surfaces and fracture region.

Keywords: Physical properties. Orthodontic wires. Scanning electron microscopy. Nickel. Titanium. Copper.

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INTRODUCTION

Since NiTi wires were first supplied in the orthodontic market, over thirty years ago, improvements have been obtained in order to enhance its performance in dental leveling and alignment. In 1963, the NiTi alloys were developed at the Naval Ordinance Laboratory of Silver Springs, Maryland, USA. In orthodontic practice, Andreasen et al^{1,2} were attracted by the unique properties inherent to these alloys, such as high elastic limit, high resilience and low module of elasticity and rigidity. For this reason, they developed the first commercial NiTi alloys aimed at orthodontic purposes.¹ Subsequently, Unitek Corporation produced the stabilized NiTi alloy for clinical use under the trade name Nitinol (Nickel Titanium Naval Ordinance Laboratory). It was developed on the weight percentage of 55% of nickel and 45% of titanium, and clinically used for the first time in 1972. Despite its excellent property of elastic recovery, Nitinol did not have, by that time, shape memory or superelasticity.

Superelastic NiTi alloys (SE NiTi) were initially produced in 1978 by Furukawa Electric Co. (Japan). Thereafter, several studies were carried out in the attempt to produce wires with similar properties for orthodontic purposes, which was achieved in 1986, with the development of the Japanese NiTi wire. Concomitantly to this discovery, another NiTi alloy with similar characteristics was developed specially for orthodontic purposes by Tien Hua Cheng at the General Research Institute for Non-Ferrous Metals (Beijing, China).⁶ These alloys, named Chinese NiTi, had unique characteristics of constant maintenance of forces during activation and deactivation.^{6,12} The austenitic crystal structure obtained during the manufacturing process significantly differs them from stabilized NiTi wires.⁶

Heat-activated NiTi alloys emerged, for commercial purposes, in the 90's. In addition to the property of maintaining the constant load of superelastic wires, thermodynamic NiTi wires had the additional characteristic of being thermally activatable, a property that is responsible for shape memory.¹² Since 1963, Buehler⁴ has observed the shape memory effect¹⁵, asserting that, in low temperatures, the NiTi alloys were easily deformed and, when heating them above their transition temperatures, their original configurations were re-established. However, the complexity

of the thermic treatment of NiTi alloys made it impossible, at that time, to manufacture heat-activated wires.^{8,17} NiTi wires with copper (CuNiTi) emerged, commercially, in the mid 90's and were manufactured in three transition temperatures, one of which was superelastic (CuNiTi 27°C) and two heat-activated (CuNiTi 35°C and CuNiTi 40°C). Due to having copper (efficient heat conductor) added to nickel and titanium, these wires present better defined transition temperatures, which not only ensures the generation of more homogeneous loadings from arch to arch and from end to end, but also increases the effectiveness of tooth movement.¹⁶

Fischer-Brandies et al¹⁰ compared the chemical composition and the superficial topography of five trade brands of rectangular superelastic NiTi wires (Dentaurum, Forestadent and Lancer) and heat-activated wires (GAC and CuNiTi 35°C). The results showed that all tested wires presented minimum differences in their chemical composition, with nearly 58% of nickel and 42% of titanium, except for the CuNiTi wire which, besides nickel (50.7%) and titanium (42.4%), presented 6.9% of copper in its composition. With regard to superficial topography, all wires presented inclusion and manufacturing residue (particles of Si and Al), chemical immunogeneicities and superficial slots. Superelastic wires presented smoother surfaces in comparison to the heat-activated ones. Such characteristics are important because they are associated with the intensity of bracket-wire attrition, biocompatibility and resistance to corrosion, given that the release of ions and the fractures caused by fatigue start on the spot of inclusion and corrosion.¹⁰

Damon⁷ stated that the specific use of CuNiTi 35°C orthodontic wires associated with self-bonding brackets (Damon system) would significantly reduce the coefficient of attrition generated in conventional mechanics, which is the key to an efficient treatment. As a result, there would be significant reduction in the mean period of chair time, the number of visits paid to the orthodontist and in patient's degree of discomfort.

In this context, the present study aimed at: (1) carrying out and comparing qualitative analyses of the chemical composition of superelastic and heat-activated NiTi and CuNiTi wires of different trade brands, through scanning electron microscopy (SEM) with EDS system of microanalysis (energy dispersive spectroscopy);

and (2) analyzing and comparing by means of SEM and the technique of secondary electrons analysis, the surface finishing as well as the fracture region of these wires, given that such characteristics could affect the clinical performance of these alloys and, more specifically, the coefficient of attrition, the biocompatibility and the adequate resistance to corrosion and to fracture under orthodontic forces.^{3,5,11,13}

MATERIAL AND METHODS

Twenty orthodontic 0.018" gauge precontoured wires were used, all of which had the same arch shape and were commercialized by six different companies. The wires were divided into two groups (superelastic and heat-activated) according to their mechanical properties which were informed by the manufacturers. Groups and subgroups of the analyzed samples are shown in Table 1. The wires were subjected to traction tests of which results are presented in part 1 of this work.¹⁸

The semiquantitative chemical composition was determined by the same methodology used by Fischer-Brandies et al.¹⁰ Surface morphology and fracture regions of the wires were analyzed by scanning electron



Figure 1 - Scanning electronic microscope used with EDS system of microanalysis.

microscopy (JEOL, model JSM-5800 LV with EDS system of microanalysis) (Fig 1). To analyze the surface morphology of the fracture region and wire-surface roughness of the wires, the technique of secondary electrons analysis was used, by means of which the images of inclusions, manufacturing residue and superficial heterogeneity were obtained. To carry out these tests, two samples of each wire subgroup were used.

Table 1 - Orthodontic wires used in this study: GAC (GAC Int. Inc. New York, USA); TP (TP Orthodontics, La Porte, USA); Ormco (Ormco Corp. Glendora, USA); 3M Unitek (Unitek Corporation, Monrovia, USA); Masel (Masel, Bristol, USA); Morelli (Dental Morelli, São Paulo, Brazil).

SUPERELASTIC GROUP (12 archwires)		HEAT-ACTIVATED GROUP (08 archwires)	
GAC	2 NiTi SE (REF. 03-018-53T)	GAC Sentalloy	2 NiTi Heat (REF. 02-511-132)
TP Reflex	2 NiTi SE (REF. 381-264)	TP HA	2 NiTi Heat (REF. 381-825)
Ormco Ni-Ti	2 NiTi SE (REF. 219-3204)	Ormco 35°C	2 CuNiTi Heat (REF. 219-4204)
Ormco 27°C	2 CuNiTi SE (REF. 205-0048)	Unitek Nitinol HA	2 NiTi Heat (REF. 4286-981)
Masel Elastinol	2 NiTi SE (REF. 4828-018)	-	-
Morelli	2 NiTi SE (REF. 50.70.014)	-	-

Table 2 - Chemical composition of tested NiTi and CuNiTi wires (EDS).

Chemical composition %	Nickel (Ni) NiO	Titanium (Ti) TiO ₂	Copper (Cu) CuO	Aluminium (Al) Al ₂ O ₃	Calcium (Ca) CaO	Bromine (Br) Br	Silicon (Si) SiO ₂
NiTi SUPER GAC	53.33%	43.52%	-	0.19%	-	-	-
NiTi SUPER TP	52.50%	45.44%	-	1.61%	0.16%	-	0.20%
CuNiTi 27°C Ormco	46.87%	43.70%	6.72%	2.31%	-	-	-
NiTi SUPER Ormco	50.99%	42.27%	-	-	3.50%	0.54%	1.98%
NiTi SUPER Masel	49.22%	39.40%	-	5.08%	0.27%	4.26%	1.42%
NiTi SUPER Morelli	53.84%	42.96%	-	2.11%	-	-	0.58%
NiTi Heat GAC	52.84%	41.61%	-	1.13%	0.27%	-	1.59%
NiTi Heat TP	53.48%	43.26%	-	0.86%	-	-	-
CuNiTi 35°C Ormco	43.82%	45.79%	5.09%	2.40%	0.99%	-	0.69%
NiTi Heat Unitek	54.08%	45.14%	-	0.32%	-	-	0.23%

RESULTS

Semiquantitative chemical composition

Chemical analyses revealed that all samples basically have Ni and Ti with minor differences in percentage. CuNiTi wires presented significant percentage of copper in addition to Ni and Ti in their composition. Microanalyses results shown in Table 2 indicate the oxides present on the surface of the analyzed wires.

Wire-surface roughness

Figures 2 and 3 show, respectively, the surface morphology of superelastic and heat-activated wires before traction tests. It can be observed that superelastic NiTi wires presented lower wire-surface roughness than the heat-activated ones.

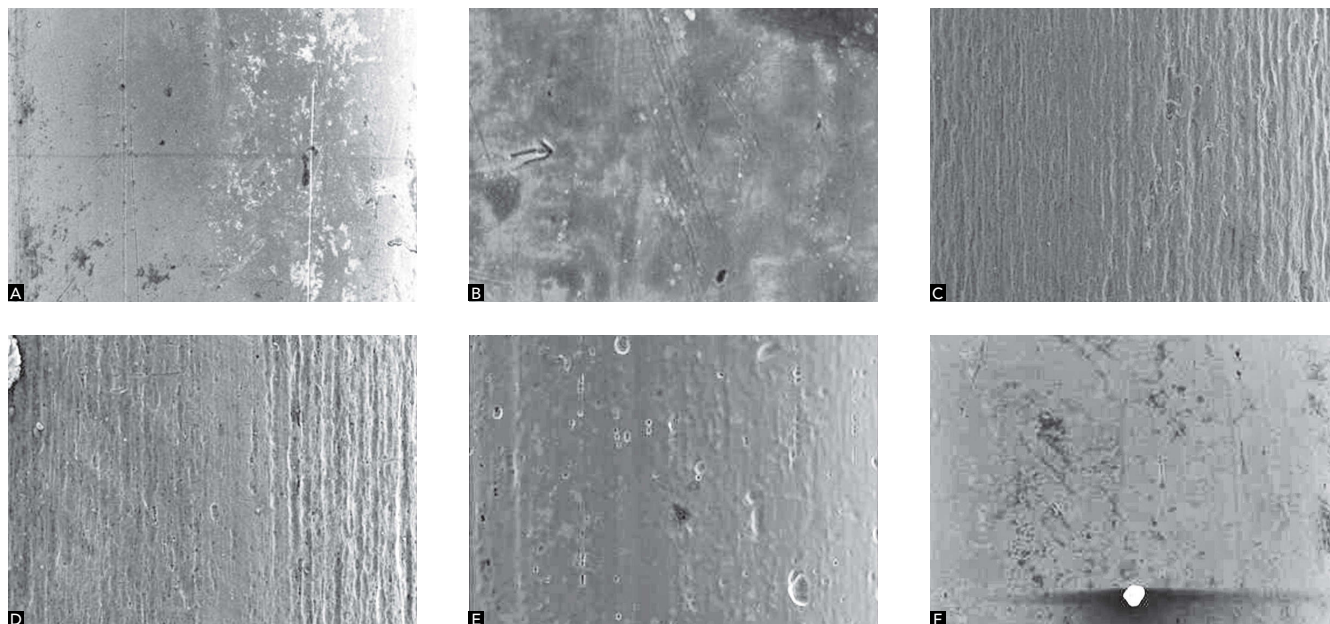


Figure 2 – Surface morphologies of superelastic NiTi and CuNiTi wires: **A)** superelastic NiTi by GAC; **B)** superelastic NiTi by TP; **C)** superelastic NiTi byOrmco; **D)** CuNiTi 27°C byOrmco; **E)** superelastic NiTi byMasel; **F)** superelastic NiTi byMorelli (X 500).

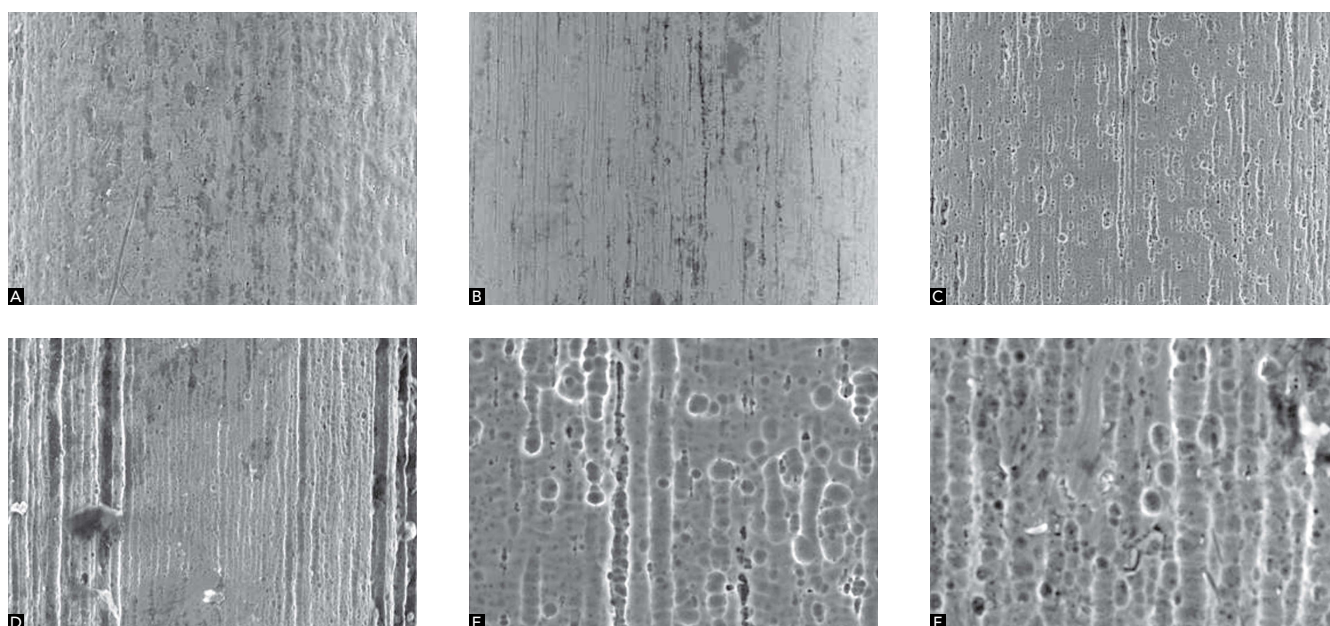


Figure 3 – Surface morphologies of heat-activated NiTi and CuNiTi wires: **A)** heat-activated NiTi by GAC; **B)** heat-activated NiTi by TP; **C)** CuNiTi 35°C byOrmco; **D)** heat-activated NiTi byUnitek (X500); **E)** CuNiTi 35°C byOrmco; **F)** heat-activated NiTi byUnitek (X 2000).

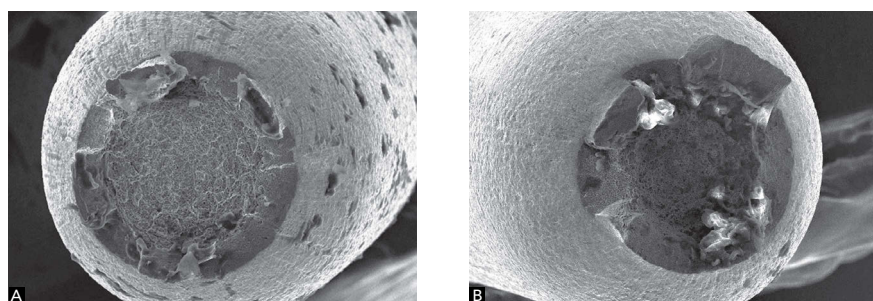


Figure 4 - Scanning electron microscopy of the fracture region on **A)** CuNiTi 27°C by Ormco and **B)** heat-activated NiTi by GAC (X 250).

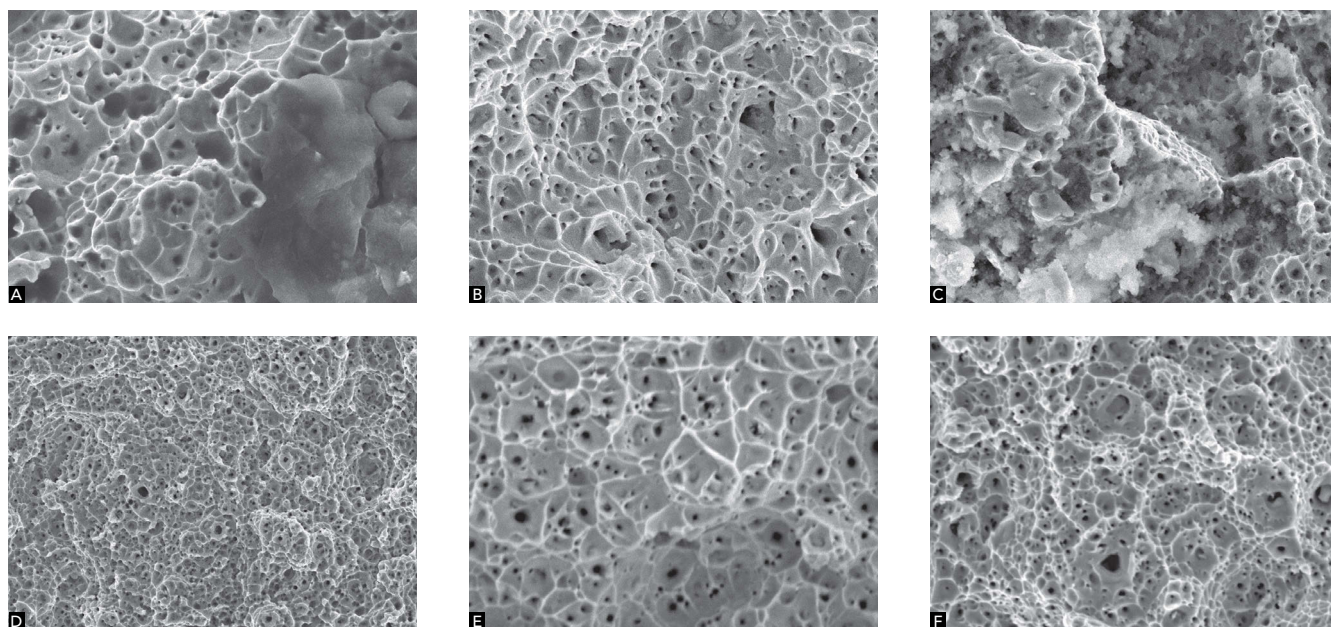


Figure 5 - Surface morphology of fracture of superelastic NiTi and CuNiTi wires: **A)** NiTi superelastic by GAC; **B)** NiTi superelastic by TP; **C)** NiTi superelastic by Ormco; **D)** CuNiTi 27°C by Ormco; **E)** NiTi superelastic by Masel; **F)** NiTi superelastic by Morelli (X 2000).

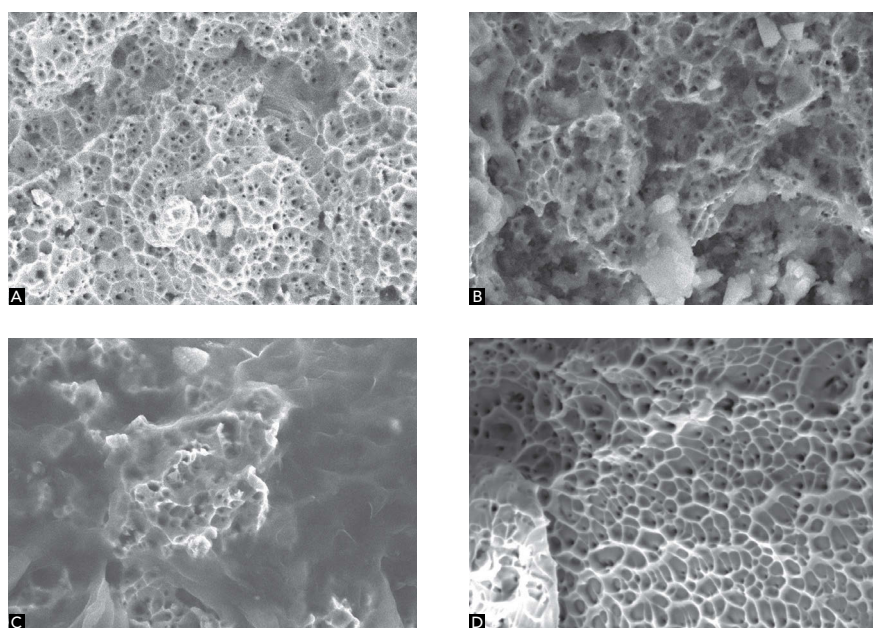


Figure 6 - Surface morphology of fracture of heat-activated NiTi and CuNiTi wires: **A)** heat-activated NiTi by GAC; **B)** heat-activated NiTi by TP; **C)** CuNiTi 35°C by Ormco; **D)** heat-activated NiTi by Unitek (X 2000).

Surface morphology of wire fracture

Figures 4 to 6 show the surface morphology of fractured NiTi and CuNiTi wires subjected to traction tests. The wires presented macroscopic plastic deformation with significant reduction in diameter. The fracture was cup-cone type, which is typical of high-ductility materials. This occurred to all subgroups of wires, implying that they underwent permanent deformations before fracturing, since they were subjected to tension and traction that were greater than their respective yield value. The analyses of fractured surfaces with greater increase (Figs 5 and 6) demonstrate the presence of microcavities, proving that the fracture is of ductile type.

DISCUSSION

With regard to the chemical composition of the tested wires, we observed that, generally, the tested NiTi wires presented Ni and Ti as the main elements of the alloy with minor differences in their composition. We also observed the presence of other chemical elements, especially Al, Si and Ca. Superelastic wires (Masel) presented a slightly lower percentage of Ni and Ti associated with a significative percentage of aluminum oxide. Superelastic wires (Ormco) presented a slightly lower percentage of Ni with higher percentage of calcium. Fischer-Brandies et al.¹⁰ suggested that all wires present inclusions, chemical immunogenicity and manufacturing residue, such as silicon oxide (SiO₂) and aluminum oxide (Al₂O₃), which was also observed in the present work.

The present work demonstrated that CuNiTi wires have a significant percentage of copper (Cu) in addition to Ni and Ti in their composition, as reported by Fischer-Brandies et al.¹⁰ According to Parvizi and Rock,¹⁴ adding between 5 and 6% of copper in the composition of superelastic NiTi wires would increase mechanical resistance and reduce the percentage of permanent deformation after deactivation, all of which are considered favorable characteristics. However, such benefits would be associated with an increase in the transition temperature of these wires for values greater than the ones found intraorally. An addition of 0.5% of chromium would be made with the purpose of avoiding such an increase and, thus, maintain the temperature at around 27°C. But, in the present work, no percentage of chromium was found in the composition of CuNiTi wires.

As for the surface morphology of wires, the manufacturing process is carried out by drawing. Drawing is the process in which wires with larger cross-sections (wire rod) pass through tools (spinnerets) to have their dimensions reduced, thus, being transformed into another wire with adequate diameter and which can be used for several purposes, for instance, as round, square and rectangle orthodontic wires. The presence and intensity of drawing marks on the surface of the wires depend on the period of use and on the spinneret finishing, on the alloy composition and on the thermodynamic state of the wire rod. Thus, the longer the period of use of the spinneret, the greater the chance of it making slots and imperfections on the surface of the wires during the process. The following is among the consequences of drawing marks: greater concentration of tension on the wires, reduction in the material capacity of being longitudinally deformed, reduction in the limit of traction resistance, increase in the coefficient of attrition and increase in biofilm adhesion.⁸

In the present work, superelastic wires presented smoother surfaces in relation to the heat-activated ones, as reported by Fischer-Brandies et al.¹⁰ Among the superelastic wires, those by Masel and Morelli (Figs 2E and 2F) presented the lowest wire-surface roughness, with evidence of polishment after the drawing process. TP and GAC wires (Figs 2A and 2B) presented intermediate wire-surface roughness. Superelastic NiTi and CuNiTi 27°C wires by Ormco (Figs 2C and 2D) presented the greatest wire-surface roughness, with deep spinneret marks, which led us to believe that they had not been subjected to any chemical or mechanical treatment after drawing.

Among the heat-activated wires (Fig 3), those by GAC, TP and Unitek as well as the CuNiTi 35°C by Ormco presented inadequate characteristics regarding wire-surface roughness, with very visible drawing marks and slots seen at any degree of magnification. Such marks were more evident and deeper in wires by Unitek and in the CuNiTi 35°C by Ormco (Figs 3C and 3D). When those wires were evaluated under magnification of 2000x (Figs 3E and 3F), they presented, in addition to drawing marks and slots, microcavities formed due to pullout of particles, possibly of NiTi,⁴ which was also observed in superelastic NiTi and CuNiTi 27°C wires by Ormco. NiTi⁴ precipitation depends on the amount of Ni in solid solution,

since it could have been altered by the presence of copper in the composition of CuNiTi wires. Variations in 0.1% of Ni would already be significant to induce the formation and precipitation of NiTi₄. As for the superelastic NiTi wires by Ormco, they presented a slightly lower percentage of Ni in comparison to the other tested NiTi wires (Table 2), which could have induced the formation of a higher percentage of precipitation and pullout of particles of NiTi₄.

With regard to the morphology of the fracture region of superelastic and heat-activated wires seen under magnification of 2000x (Figs 5 and 6), we observed the presence of microcavities which are a characteristic of ductile fractures, with the largest microcavities being formed by pullout of particles, possibly of NiTi₄. Additionally, we observed that, in general, the size of the microcavities found for superelastic NiTi wires was larger than that found for heat-activated NiTi wires. Among the superelastic NiTi wires, those that presented the smallest microcavities were the CuNiTi 27°C ones (Fig 5D). Wires by GAC, TP, Masel and Morelli (Figs 5A, 5B, 5E and 5F) presented microcavities of similar sizes. Among the heat-activated wires, those by GAC and Unitek (Figs 6E and 6H) presented smaller microcavities in comparison to wires of other samples.

The results of the present work showed that CuNiTi 35°C wires presented inadequate characteristics regarding superficial topography, which could predispose a higher coefficient of attrition during tooth movement. Damon,⁷ however, asserted that the sequential use of orthodontic wires of CuNiTi 35°C 0.014", 0.014" X 0.025" and 0.018" X 0.025" in self-bonding brackets would significantly reduce the coefficient of attrition generated in conventional mechanics, which would be the key to a more efficient treatment, with significant reduction in the mean period of chair

time, in the number of visits paid to the orthodontist and in patient's degree of discomfort.

Nevertheless, a new research should be carried out in order to evaluate the attrition of such wires in relation to other superelastic and heat-activated NiTi and CuNiTi wires, given that through scanning electron microscopy, the present work, in agreement to results obtained by Fischer-Brandies et al,¹⁰ proved that CuNiTi 35°C wires by Ormco presented not only very visible drawing marks and slots seen under any degree of magnification, but also microcavities formed due to pullout of particles of NiTi₄, which could generate a higher coefficient of attrition.

CONCLUSION

1. With regard to chemical composition, the tested NiTi wires presented predominance of Ni and Ti with a small percentage of Al, Ca, and Si. CuNiTi wires presented a significant percentage of copper in addition to Ni and Ti in their compositions.
2. With regard to surface morphology, the superelastic NiTi wires by Masel and Morelli presented the lowest wire-surface roughness, while the superelastic and heat-activated NiTi and CuNiTi wires by Ormco presented the greatest wire-surface roughness.
3. With regard to the morphology of fracture regions, CuNiTi 27°C wires by Ormco and the heat-activated wires by GAC and Unitek presented the smallest microcavities, while CuNiTi 35°C by Ormco presented the largest.
4. All wires presented fractured surfaces under ductile traction.
5. CuNiTi 35°C wires did not present better morphologic characteristics on surfaces and fracture regions in comparison to the other wires.

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Shear bond resistance and enamel surface comparison after the bonding and debonding of ceramic and metallic brackets

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Objective: To evaluate, *in vitro*, the shear bond strength presented by three brands of polycrystalline ceramic brackets and one brand of metallic bracket; verify the adhesive remnant index (ARI) after the tests, and analyze, through scanning electron microscopy (SEM) the enamel surface topography after debonding, detecting the release of mineral particles.

Methods: Sixty bovine lower incisors were used. Three ceramic brackets (Allure[®], InVu[®], and Clarity[®]) and one metallic bracket (Geneus[®]) were bonded with Transbond XT[®]. Kruskal-Wallis's test (significance level set at 5%) was applied to the results of share bond and ARI. Mann Whitney's test was performed to compare the pairs of brackets in relation to their ARI. Brown-Forsythe's test (significance level set at 5%) was applied to the results of enamel chemical composition. Comparisons between groups were made with Games-Howell's and the Post-hoc tests.

Results: No statistically significant difference was observed in relation to the shear bond strength loads. Clarity[®] brackets were the most affected in relation to the surface topography and to the release of mineral particles of enamel (calcium ions).

Conclusion: With regard to the ARI, there was a prevalence of score 4 (40.4%). As for enamel surface topography, the Geneus[®] bracket was the only one which did not show superficial tissue loss. The InVu[®] and Clarity[®] ones showed cohesive fractures in 33.3% and the Allure[®] in 50%, the latter being the one that presented most fractures during removal.

Keywords: Shear bond strength. Tooth enamel. Orthodontic brackets. Scanning electron microscopy.

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INTRODUCTION

The need for esthetic orthodontic treatment, especially by adults, culminated in the development of the first ceramic brackets in the late 1980's. Since then, new technologies for manufacturing esthetic brackets have been developed.¹⁰ Ceramic brackets may be monocrystalline or polycrystalline, according to the manufacturing process. Polycrystalline brackets are produced by precipitation of aluminum oxide particles blended with a binder, and then textured and fired to remove surface imperfections and stress, caused by the cutting process. This manufacturing process may produce structural failures in the accessories. Monocrystalline brackets are produced by a completely different process. Single sapphire crystals involve the combination of aluminum oxide particles at 2,100°C.^{13,19} The crystalline structure of monocrystalline brackets has higher purity than that of polycrystalline ones, with fewer structural failures but higher manufacturing costs.³

Bracket bonding became a routine in orthodontic treatment with fixed appliances after Buonocore⁴ introduced the technique of acid-etching the enamel surface. Buonocore⁴ proposed that the enamel surface could be modified by acids in order to become more receptive to bonding. The technique consisted in enamel prophylaxis, in which the enamel is cleaned, dried and freed from saliva, followed by application of acid on its surface. Several materials have been developed for this purpose. Due to presenting adhesive properties,⁴ composite resins have become the main bonding material.

When a bracket is removed, bond failure may occur in the bracket/adhesive interface (adhesive), in the adhesive/enamel interface (adhesive), in the adhesive layer (cohesive), or both (adhesive and cohesive). Failures in the adhesive/enamel interface lead to a higher risk of having enamel fragments removed along with the bracket base resin. Therefore, many authors suggest that the orthodontist use a technique that promotes failure in the bracket/adhesive interface in order to prevent damage to the tooth structure.^{2,4,11,12,14,24}

Due to a great difficulty in obtaining extracted human teeth for dental research, a substitute, with similar physical characteristics, has become necessary. Human teeth are morphologically and

histologically similar to the teeth of other mammals. Thus, bovine incisors have become a good option in dental research, as they are adequate in size and easily available.⁵

The shear bond test is one of the most simple and widely used tests for determining adhesion resistance of bonded orthodontic brackets.⁸ In this test, the bond is fractured with the application of a force parallel to the adhesive interface. The test may be conducted with a metallic blade or a steel wire loop, as close as possible to the adhesive interface.⁸ Failure starts at the point where the blade applies a normal force, therefore, failure does not always happen at the weakest point.²³

Scanning electron microscopy (SEM) has a wide range of applications in different fields of knowledge, and provides detailed structural information with a wide magnification range (up to 300,000X). SEM may be coupled to an X-ray energy dispersive spectroscopy (X-EDS) system, which allows the qualitative and semi-quantitative composition of the samples to be determined through emission of characteristic X-rays.⁷

In vivo studies may have several variables which can be minimized by *in vitro* research protocols performed with standard procedures and variables as limited as possible, thus yielding more representative and amenable-to-comparison results. The purpose of this study was to perform *in vitro* assessments of the shear resistance of three commercial brands of polycrystalline ceramic orthodontic brackets, using SEM to analyze the superficial enamel topography after bracket debonding and detect the release of mineral particles.

Proposition

1. Assess, *in vitro*, the shear resistance of three commercial brands of polycrystalline ceramic orthodontic brackets and of one metallic orthodontic bracket, all with mechanical retention.
2. Assess, by means of light microscopy, the adhesive remnant index (ARI) after bracket removal;
3. Assess, with SEM, the enamel superficial topography after bracket debonding.
4. Detect, by means of SEM adapted with an X-EDS microanalysis system, the release of mineral particles from the enamel after removal of ceramic and metallic brackets.
5. Observe and calculate bracket fracture during removal.

MATERIAL AND METHODS

Sixty recently extracted bovine lower incisors were obtained from the Municipal Abattoir of Juiz de Fora. The inclusion criteria demanded that the teeth had intact buccal surfaces, and no cavities, fractures, stains or enamel lesions.

All teeth were examined under light microscopy with a stereomicroscope (Stemi 2000C, Zeiss), at the Department of Physics of the Federal University of Juiz de Fora. After selection, the teeth were immersed for seven days into a 0.1% thymol-water solution¹⁷ at room temperature, for asepsis and dehydration prevention. After this period, the remaining soft tissues, calculi and root-adhered bone fragments were removed.¹⁷

All teeth were subsequently kept at distilled water at 4°C, which was replaced every seven days, for a period not greater than three months before inclusion in the molded samples. Before inclusion, the teeth had their radicular tips sectioned so as to have the same radicular length.¹⁶ Prior to plaster casting, carborel disk retentions were performed in the roots in order to increase their retention.

Three commercial brands of polycrystalline ceramic orthodontic brackets (Allure /GAC; InVu /TP and Clarity/3M-Unitek) and a metallic orthodontic bracket brand (Geneus/ GAC), all with mechanical retention, were used. They were divided into four groups with 15 brackets each. The study was conducted in two parts: 1) shear test; 2) SEM with X-EDS microanalysis.

To build the molded samples, 26 mm high PVC pipes with a 25 mm internal diameter were used. The molded samples were filled with type IV pink stone plaster¹⁶ (Vigodent, Bonsucesso, Rio de Janeiro, Brazil). For bracket bonding, the teeth underwent prophylaxis of their buccal surfaces, with pumice stone and water, and were brushed with a Robinson's brush in low-rotation. The teeth were then washed with water for 10 seconds, and dried with an oil-free and humidity-free air spray.

All brackets were bonded with the Transbond XT adhesive (3M Unitek Orthodontics Products, Monrovia, USA), according to the manufacturer's instructions. The teeth were initially immersed into a 37% phosphoric acid solution (Condac 3M, FGN, Joinville, Santa Catarina, Brazil) for 15 seconds, sprayed with

water for 10 seconds, and dried with an air spray. By the end of the process, they acquired a chalk-white color.

The adhesive (Primer Transbond XT, 3M Unitek Orthodontics Products, Monrovia, USA) was applied and light-cured for 10 seconds.⁴ At last, the brackets were positioned at the center of the buccal surfaces, excess resin was removed and a light-curing process was performed for 20 seconds (ceramic brackets) and 40 seconds (metallic brackets). The Opti Light digital light curing device (Gnatus, São Paulo, Brazil) was used. After bonding, the teeth remained immersed in distilled water at 37°C, for 24 hours.

In order to standardize the molded samples for the shear test, a 0.021 x 0.025-in rectangular steel wire guide, inserted into the bracket slots and fixed with elastomeric ligatures, was used for positioning the teeth in the PVC pipes. This device allowed the brackets to remain at the same distance from the molded sample bases, and the buccal surfaces of the teeth to lie on a vertical plane parallel to the blade of the testing machine. Thus, all the molded samples were positioned at the base of the testing machine in such a way that the cleaver would be placed between the base and the occlusal tying-wings of the brackets, directing the force to an axis that was parallel to the bonding surface.

The mechanical shear tests were performed in a universal testing machine (EMIC DL 2000) adapted with a microprocessor, at the Post-Graduation Laboratory of the School of Dentistry — Federal University of Juiz de Fora. A 50 Kgf load cell was used at a 0.5 mm/min testing speed. For bracket debonding, the shear load values applied were gradually increased. The data obtained from these tests were stored in a computer directly linked to the mechanical testing device.

In order to analyze the morphology of the enamel debonding surfaces, the secondary electron analysis technique, through SEM (JEOL, JSM5800 LV), was performed at the Military Engineering Institute of Rio de Janeiro. All the images were under magnification of 200X for observation of the entire surface from which photographs were obtained. To detect enamel mineral chemical elements in the debonding surfaces, SEM with X-EDS microanalysis was employed. This test assessed the damage inflicted to the enamel after debonding, being performed in only five

teeth of each group (the ones with the smallest ARI).

In addition, two other variables were assessed: 1) ARI after debonding and; 2) frequency of cohesive bracket fractures during the shear tests.

Therefore, all dental elements were analyzed and classified taking into account their ARI^{1,6} after bracket removal. The scores ranged from zero to five, as follows: (0) no resin remained adhered to the tooth after debonding; (1) less than 25% of resin remained adhered to the tooth after debonding; (2) between 25 and 50% of resin remained adhered to the tooth after debonding; (3) between 50 and 75% of resin remained adhered to the tooth after debonding; (4) more than 75% of resin remained adhered to the tooth after debonding and; (5) all resin remained adhered to the tooth after debonding.^{1,6}

The results were statistically analyzed and the Shapiro-Wilk's test did not show normal distribution in the sample. Levene's test demonstrated the homoscedasticity of the sample, while Kruskal-Wallis's test was used, with a significance level set at 5%, to obtain the shear test results and calculate the adhesive remnant index (ARI) in the enamel. Furthermore, Mann-Whitney's test, with a significance level set at 1.25% (equivalent to 0.05/4), was used to compare pairs of brackets with regard to their ARI.

To analyze the chemical composition of the enamel (X-EDSD), Brown-Forsythe's test, with a statistical significance of 5%, was used. Comparisons between groups were made with the Post-hoc and Games-Howell's tests.

RESULTS

Table 1 presents the results (in MPa) of the mechanical shear tests. The mean shear resistance values were as follows: GI (9.97 ± 5.29); GII (11.74 ± 4.52), GIII (10.91 ± 4.37); GIV (12.71 ± 5.81). Kruskal-Wallis's test (5% significance) had $P = 0.43$, showing that no group differed from one another with regard to the central tendency.

GI (Geneus®) was the only group that did not show bracket fracture during the mechanical testing. On the other hand, GII (Allure®) had 50% of its brackets with cohesive fractures, while GIII (InVu®) and GIV (Clarity®) had fractures of five brackets each, corresponding to 33.3% of the sample in each group. Out of the total number of ceramic

brackets used ($n = 44$), 17 fractured, which represents 38.63% of the sample.

As for the ARI results, some teeth could not be analyzed, as the whole bracket base remained adhered to the crown after removal. The results of this analysis are shown in Table 2. Kruskal-Wallis's Test (5% significance) had $P = 0.03$, showing statistically significant differences between groups with regard to the central tendency.

Table 3 shows the differences between pairs with regard to ARI (Mann-Whitney's Test). The pairs were analyzed with a general significance level ($P = 0.003$), and with specific significance levels not greater than 0.0125 (0.05/4). Statistically significant differences were observed between the following brackets: Clarity® and InVu® ($P = 0.002$); Allure® and InVu® ($P = 0.006$) and Clarity® and Geneus® ($P = 0.002$). The other comparisons yielded no statistically significant differences.

Five teeth from each group were selected for enamel analysis with SEM. The choice was based on the molded samples with the smallest ARI value in each group. Since these samples would supposedly have suffered the greatest enamel damage after the shear test, they would probably allow better visualization of the enamel surface. After individual analysis of the 20 teeth (5 from each group) under SEM, all molded samples were found to have microscopic enamel topographic characteristics that were similar within groups. These characteristics are shown in Figures 1 to 4.

All molded samples selected for SEM analysis were also submitted to X-EDS for analysis of the enamel chemical composition.

Table 1 - Means, standard deviation, minimum and maximum values and number of teeth regarding the mechanical shear tests (MPa).

Group	Mean $\pm$ SD	Minimum	Maximum	Number of teeth
I) Geneus	9.97 ± 5.29	4.05	17.71	15
II) Allure	11.74 ± 4.52	5.72	22.00	15
III) InVu	10.91 ± 4.37	4.93	17.34	15
IV) Clarity	12.71 ± 5.81	6.16	23.22	15
Total	11.33 ± 5.01	4.05	23.22	60

Kruskal-Wallis' test. $p = 0.43$.

Table 4 presents the data referring to the chemical composition, described by means and intra-group standard deviations of the percentages of the chemical elements found. Because most chemical elements found were not present in all groups of brackets, statistical analysis was precluded for most of them.

Only comparative analysis of calcium could be performed, at it was the only chemical element present in all groups of brackets. To this end, Brown-Forsythe's test was used, given that neither Kolmogorov-Smirnov's and Shapiro-Wilk's normality tests nor

Levene's equality of variance test found variance normality and similarity between groups.

It is important to point out that, out of all chemical elements found with X-EDS, calcium percentages should be the most noteworthy in the enamel, as higher values would indicate minor damage to the enamel after bracket removal, whereas lower values would suggest severe damage. This is the reason why only the data referring to calcium were presented in this study. The Brown-Forsythe's test reached 5% statistical significance for calcium.

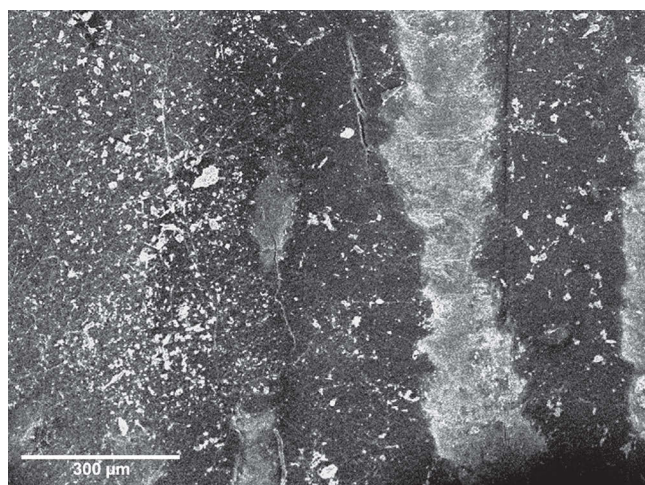


Figure 1 - Enamel sample from the Geneus® group, with no superficial tissue loss, showing only small fissures, probably due to the debonding technique.

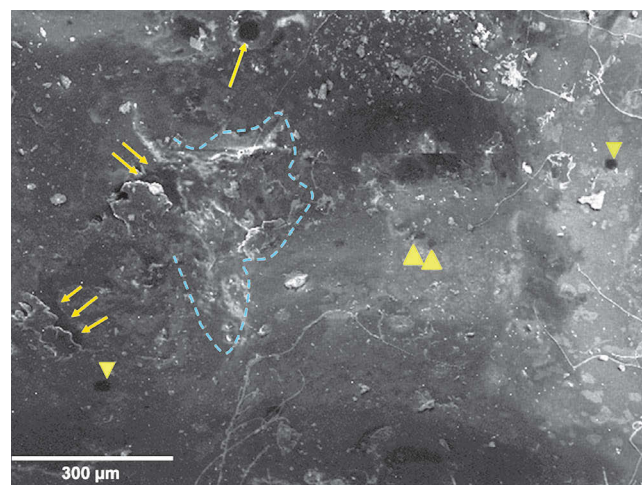


Figure 2 - Enamel sample from the Allure® group, showing erosions (yellow arrow) and well-established pores (green arrow point), depressions (orange arrow) and slight loss of the aprismatic enamel layer (blue dotting).

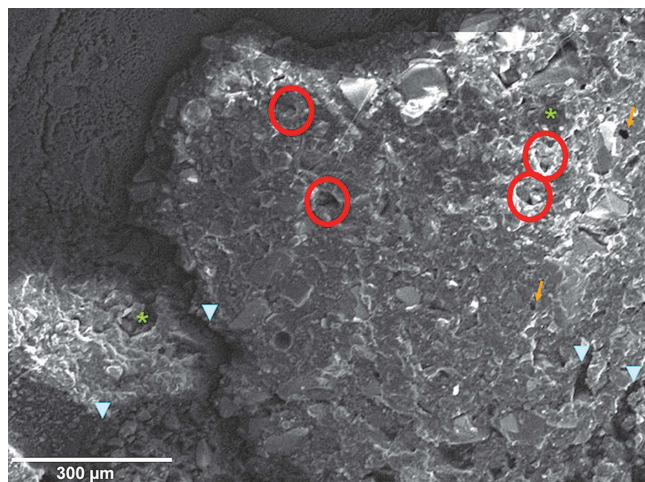


Figure 3 - Enamel sample from the InVu® group, showing small craters (green asterisk) surrounded by areas of loss of the aprismatic enamel layer, pores (orange arrow), erosions (red circle) and depressions (blue arrow heads).

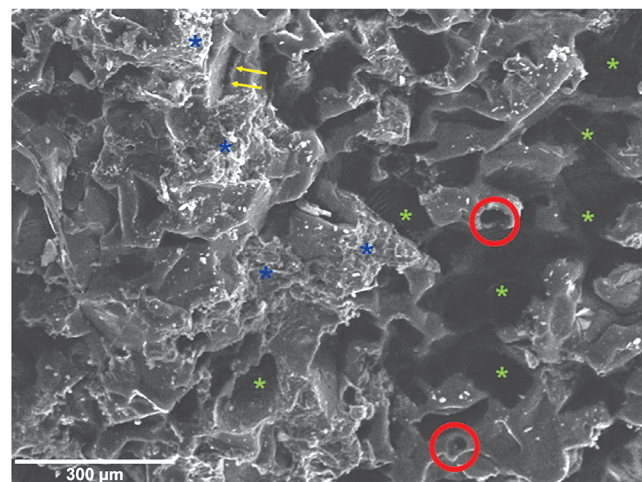


Figure 4 - Enamel sample of the Clarity® group, showing significant alterations of the enamel microstructure, with electron-lucent areas, corresponding to craters characteristic of "erosion deepening" (green asterisk), surrounded by extensive loss of the aprismatic enamel layer (blue asterisk) and depressions (yellow arrows) and some erosions (red circle).

Table 2 - Scores for ARI assessment in the study groups.

ARI groups	Scores						Total
	0	1	2	3	4	5	
I) Geneus	0 (0%)	5 (33.3%)	4 (26.7%)	0 (0%)	2 (13.3%)	4 (26.7%)	15
II) Allure	0 (0%)	0 (0%)	1(7.1%)	0 (0%)	9 (64.3%)	4 (28.6%)	14
III) InVu	2 (20%)	1(10%)	2 (20%)	1(10%)	4 (40%)	0 (0%)	10
IV) Clarity	0 (0%)	0 (0%)	0 (0%)	1(7.7%)	6 (46.2%)	6 (46.2%)	13
Total	2	6	7	2	21	14	52

Table 3 - Differences between bracket pairs, according to the ARI.

	Geneus (I)	Allure (II)	InVu (III)	Clarity (IV)
I) Geneus		0.057	0.605	0.002*
II) Allure	0.057		0.006*	0.488
III) InVu	0.605	0.006*		0.002*
IV) Clarity	0.002*	0.488	0.002*	

Table 4 - X-ESD results referring to the mean percentages of calcium present in tooth enamel and their statistical analysis.

Group	Mean	Bracket	Bracket	Mean difference	Mean standard error	p-value
Geneus	52.77	Geneus	Allure	19.10800	13.90868	0.564
			InVu	-7.54000	4.50529	0.421
			Clarity	45.56600 (*)	4.94396	0.000
Allure	33.66	Allure	Geneus	-19.10800	13.90868	0.564
			InVu	-26.64800	13.34571	0.320
			Clarity	26.45800	13.50011	0.327
InVu	60.31	InVu	Geneus	7.54000	4.50529	0.421
			Allure	26.64800	13.34571	0.320
			Clarity	53.10600 (*)	3.01652	0.000
Clarity	7.20	Clarity	Geneus	-45.56600 (*)	4.94396	0.000
			Allure	-26.45800	13.50011	0.327
			InVu	-53.10600 (*)	3.01652	0.000

The Post-hoc and Game-Hoewel's tests were used for comparison between groups, with the Clarity® group showing statistically lower percentages of calcium in comparison with the Geneus® and InVu® groups. As for the Allure® group, no statistically significant difference was found between the former and the other groups (Table 4).

DISCUSSION

Santos et al¹⁷ and Vicente et al²¹ demonstrated the superiority of Transbond XT® in comparison with glass ionomer cements, with higher bracket adhesive resistance to enamel and higher percentage of fractures in the bracket-adhesive interface. This is the reason why this was the material chosen in this study.

All brackets were conventionally bonded as proposed by Buonocore⁴ in 1955, that is: prophylaxis of the bonding dental surfaces, acid etching, application and light-curing of the Transbond XT[®] adhesive and bonding with the Transbond XT[®] resin. Romano¹⁵ reported the need for acid etching of the enamel to reach shear resistance values that were compatible with clinical use. Savaris and Menezes,¹⁸ on the other hand, did not observe statistically significant differences in the shear loads between samples in which the Transbond XT adhesive (primer) was light-cured and samples in which no light-curing process was performed. We chose to proceed with acid etching of the enamel and light-curing of the adhesive, as this is a traditional protocol used in shear and enamel surface analysis research.

The mechanical shear tests were performed 24 hours after bracket bonding, with the molded samples being kept in distilled water during this period. We chose this time interval in accordance with Hajrassie and Khier⁹ who did not observe significant differences, *in vitro* or *in vivo*, in the debonding loads of metallic brackets bonded to premolars with Transbond XT[®] after four different bonding times: 10 minutes, 24 hours, 1 week and 4 weeks.

As for the values obtained with the mechanical shear tests (loads between 9.97 and 12.71 MPa), we concluded that all brackets studied could be successfully used in a clinical scenario, given that the minimum shear resistance loads necessary to tooth movement range from 5.9 to 7.9 MPa, according to Vasques et al.²⁰

Cohesive fractures were observed in the three commercial brands of ceramic brackets, with 33.3% for Invu[®] and Clarity[®], and 50% for Allure[®]. No fractures were observed in the group of metallic brackets. As for SEM, the samples of the Clarity[®] group had significant alterations in the enamel microstructure in comparison with the other groups, with electron-lucent areas corresponding to craters, erosion deepening and extensive loss of the aprismatic enamel layer. This was confirmed by X-EDS, in which the Clarity[®] group had a significantly lower percentage of calcium in the enamel after bracket removal. Likewise, Chen et al⁶ observed cohesive fractures in 25% of the Clarity[®] brackets after machine-driven debonding. On the

other hand, in the same study, Chen et al⁶ observed by means of SEM that most fractures occurred in the bracket/adhesive interface, with no significant enamel damage after bracket removal. However, it is noteworthy that Chen et al⁶ submitted their total sample to SEM with X-EDS microanalysis, whereas in the present study only the teeth with smaller ARI were analyzed, which might have contributed to less favorable results concerning the superficial topography of the enamel.

Savaris and Menezes¹⁸ as well as Chen et al⁶ did not observe damage or important fractures in the enamel surface after removal of the Clarity[®] brackets bonded to bovine teeth, reporting that debonding predominantly occurred in the resin layer (cohesive failure, ARI 3), with enamel fracture in just one of the 60 teeth analyzed. Similarly to the study conducted by Chen et al,⁶ the whole sample was submitted to SEM.

Substantial enamel loss and significant enamel damage were observed under SEM analysis for all groups of ceramic brackets. Vilchis, Hotta and Yamamoto²² used SEM to observe the superficial enamel topography of premolars submitted to bracket bonding according to two methods: (1) etching with 37% phosphoric acid for 30 seconds + Transbond XT[®] adhesive + Transbond XT[®] resin cement; and (2) Transbond Plus Self Etching Primer[®] (SEP) + Transbond XT[®] resin cement. Based on the yielded results, they demonstrated that the phosphoric acid etching group had greater enamel loss in comparison to the Transbond Plus Self Etching Primer[®] group. Additionally, the enamel-adhesive interfaces had more irregularities with phosphoric acid etching. The differences between our findings and some literature reports may be related to such etching, as phosphoric acid was used in our study.

In a search for a more conservative orthodontic bonding, we suggest that further studies comparing Transbond Plus Self Etching Primer[®], 37% phosphoric acid and other etching materials be undertaken to identify the orthodontic material causing the least enamel damage after bracket removal. This study demonstrated that enamel damage after bracket removal can occur in teeth conditioned with 37% phosphoric acid, with this damage being more frequent and extensive when ceramic brackets are used.

CONCLUSION

1. There were no statistically significant differences between groups with regard to the shear loads necessary to promote bracket debonding.
2. As for the adhesive remnant index, there were statistically significant differences between the following groups: Clarity® and Invu®; Allure® and InVu®; Clarity® and Geneus®. No statistically significant differences were found between other pairs. In a general context, score 4 prevailed, with 40.4%.
3. Analysis of the enamel superficial topography showed that the Geneus® group was the only one with no superficial tissue loss, having suffered only small fissures, probably due to the debonding technique. All ceramic bracket groups had erosions, pores, depressions and loss of the aprismatic enamel layer, with the Clarity® group being most affected, with significant alterations in enamel microstructure.
4. As for the X-EDSD, the Clarity® group had a significantly lower percentage of calcium in the enamel after bracket removal.
5. Metallic brackets did not fracture during removal. The InVu® and Clarity® groups had fractures in 33.3% of their samples, while the Allure® group had fractures in 50%.

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Comparison of friction produced by two types of orthodontic bracket protectors

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Introduction: Fixed orthodontic appliances have been regarded as a common causative factor of oral lesions. To manage soft tissue discomfort, most orthodontists recommend using a small amount of utility wax over the brackets in order to alleviate trauma. This *in vitro* study aimed at evaluating friction generated by two types of bracket protectors (customized acetate protector [CAP] and temporary resin protector [TRP]) during the initial stages of orthodontic treatment.

Methods: An experimental model (test unit) was used to assess friction. In order to measure the friction produced in each test, the model was attached to a mechanical testing machine which simulated maxillary canines alignment. Intergroup comparison was carried out by one-way ANOVA with level of significance set at 5%.

Results: The friction presented by the TRP group was statistically higher than that of the control group at 6 mm. It was also higher than in the control and CAP groups in terms of maximum friction.

Conclusion: The customized acetate protector (CAP) demonstrated not to interfere in friction between the wire and the orthodontic bracket slot.

Keywords: Orthodontics. Orthodontic brackets. Friction.

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INTRODUCTION

Fixed orthodontic appliances have been regarded as a common causative factor of oral ulcers and cellular alterations due to an intermittent friction between the oral mucosa and the orthodontic brackets.^{1,2} Such problem invariably leads to discomfort for both lingual and oral mucosa.³

To manage soft tissue discomfort commonly associated with fixed orthodontic appliances, most orthodontists recommend the use of a small amount of utility wax over the brackets in order to alleviate trauma. This is perhaps one of the most traditional ways of protecting soft tissues during orthodontic treatment. Although incorporation of anesthetic compounds has been reported,¹ no further investigation has been published on this type of protection. Other materials such as temporary restorative resins⁴ (e.g. Fermit™) or even plastic materials have recently been used to cover brackets; however, the literature still lacks data on biocompatibility and influence of these materials on biomechanics.

With regard to orthodontic biomechanics specifically, previous studies have shown that the continued use of protectors (plastic or resin based) can increase friction between the wire/ligatures and the orthodontic bracket.⁵⁻¹³ Ideally, it would be desirable that materials used over brackets did not interfere in or even touch the wire and the bracket slot during orthodontic tooth movement.

An acetate protector customized for each type of bracket, bearing the aforementioned concept of not interfering with either the wire or bracket slot, was developed for the present study. Such type of protector still needs to be validated through a randomized controlled trial (RCT) before its use can be fully recommended. However, it would be unethical to start an RCT without first checking whether this type of protector design could interfere in orthodontic movement. To date, it appears that no study has yet been published on the use of such device, or even on its influence in relation to friction development.

The aim of the present *in vitro* study was to compare the friction generated by two different groups of bracket protectors when simulating the leveling of a maxillary canine: (1) Brackets covered with a customized acetate protector, fabricated for the present study, and (2) Brackets covered with a temporary composite resin. Both groups were compared to a control group with no protection.

MATERIAL AND METHODS

Type of brackets

The preadjusted brackets (Roth prescription, Dental Morelli, São Paulo, Brazil) used in the present study were made of stainless steel 0.022-in slot, specifically designed for right upper premolars, canines and lateral incisors. Except for the lateral incisor bracket, all of them contained a hook.

Experimental groups

Three groups were created in order to compare the degree of friction: CAP group, with brackets covered with a customized acetate protector (CAP); TRP group, with brackets covered with a temporary resin protector (TRP); and control group, with brackets without protection for soft tissues. Twenty-one friction tests were performed on each group. The number of tests was determined by a sample size calculation based on a pilot study with 10 tests, in which a difference of 1 N among the means was considered to be clinically significant. For this calculation, the power of the test was set at 80%, and the level of significance at 5%.

Fabrication of the customized acetate protectors, as used in CAP group

The customized acetate protectors (CAP) used to cover metallic bracket surfaces (Dental Morelli, São Paulo, Brazil) were fabricated by a single calibrated operator. The calibration process included fabrication of a series of different protectors, and was determined upon the authors' satisfaction with the quality of the protectors produced. Sixty protectors were fabricated for each type of bracket used in the study. Direct contact of the acetate material with either the orthodontic wire or the bracket slot was avoided by relieving the slot of each bracket with light-activated Z100 composite resin (3M, St. Paul, MN, USA). Such relief is part of the protector fabrication process. It is something that needs to be done only on the brackets used for fabrication, not on the brackets where the protectors will be used. Clinically, the rationale is exactly the same, and the relief is hence unnecessary on the brackets used by the patient.

The brackets were then placed in a vacuum thermoforming machine so as to obtain a 1 mm-thick acetate pellicle. The acetate was cut with 0.5-mm steel discs which were set on a slow speed straight handpiece. The cutting procedure was performed in such a way so

as to restrict the protector to the bracket surfaces that normally touch soft tissues. During this procedure, any areas or points of contact between the orthodontic wire and the acetate material were removed.

Fabrication of temporary resin protectors, as used in the TRP group

Temporary resin protectors (TRP) consisted in the application of a standardized quantity of Fermit composite (Ivoclar Vivadent Inc., Amherst, NY, USA) on the center of the bracket by means of light digital pressure. This procedure simulated the clinical application of this material as a soft tissue protector for orthodontic patients.

In order to avoid excess, the amount of composite resin applied was standardized. Such standardization was obtained by dispensing a 2-mm long straight line of resin over a millimetric ruler. This amount was enough to protect each bracket. Any possible excess touching the wire outside the slot was removed with the aid of an explorer.

Friction evaluation

The *in vitro* experimental model (test unit) used to assess friction was based on a previously described methodology,¹⁴ in which the right buccal segment of the upper arch containing five stainless steel 0.022-inch preadjusted brackets (from the second premolar through the central incisor) was reproduced.

One of the main differences between the model used and that already described¹⁴ is the height of the maxillary canine: 6 mm in the present study, and 3 mm in the previous publication.

Brackets were passively aligned with a 0.0215 x 0.028-in stainless steel wire (Dental Morelli, São Paulo, Brazil). The next step consisted in attaching them to the vertical metallic bars of the test unit by using superbond glue (Loctite Brand - Consumer Products, Henkel Corporation, Westlake, Ohio, USA). The gluing procedure was preferred to the mechanism described for the original prototype¹⁴ because of greater stability. The interbrackets distance was 6 mm. The only metallic bar allowed to move was the one containing the bracket for the maxillary canine. During the whole procedure, no accidental bracket debonding was observed.

The tests were performed with 0.014-in superelastic nickel titanium wires tied to the bracket slots by means of elastic ligature ties (Dental Morelli, São Paulo, Brazil). The model simulated a severely crowded maxillary canine. As the simulated hemiarch did not have a parabolic shape, the segments of wire used in this study were straight, and measured 55 mm in length. Every wire segment received standardized cuts, and was installed into the test unit with a 7.5 mm wire excess in both extremities of the hemiarch. The wire, ligature tie and bracket protectors (CAP and TRP) were replaced by new ones before the start of each test.

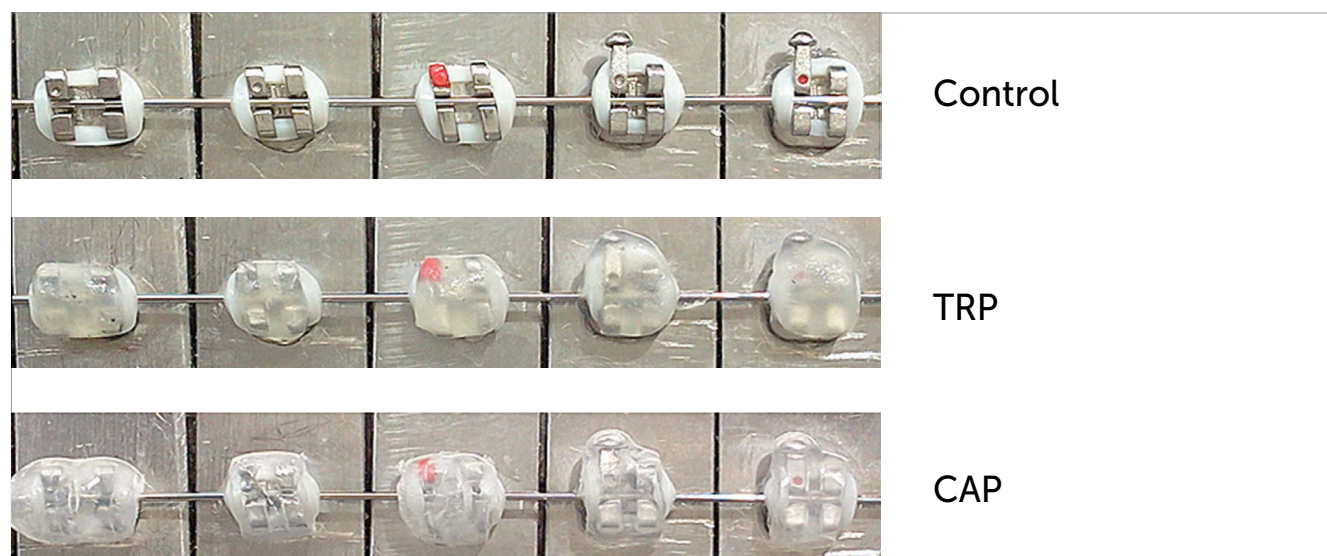


Figure 1 - Two systems containing protected brackets (CAP - customized acetate protector and TRP - temporary resin protector), and one system without protected brackets (control).

The same experimental model and brackets were used throughout the study. Figure 1 illustrates each system separately (CAP, TRP and control).

In order to measure the friction produced in each test, the model was attached to a mechanical testing machine (Shimadzu, AG-1, 250kn, Tokyo, Japan) that had been previously calibrated by the manufacturer (Fig 2).

Instead of pulling the wire ends to align the maxillary crowded canine, it was preferred to elevate the mobile metallic bar from a position leveled 6 mm above. This proved to be useful to eliminate small random friction variations between the mobile and adjacent fixed metallic bars. The mobile metallic bar was elevated by the capture mechanism of the testing machine, using a 10 N load cell. This adaptation produced a mean friction value

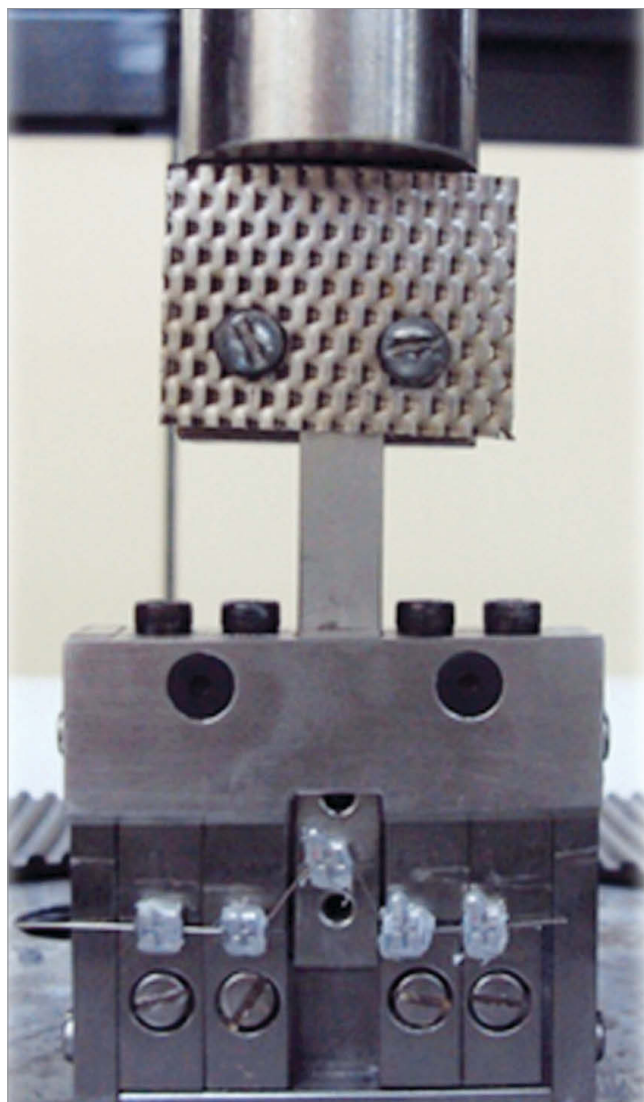


Figure 2 - Tensile strength of 6 mm being performed on the vertical bar of the experimental model, by a mechanical testing machine.

close to zero in several pre-tests performed without orthodontic wire at a speed of 6 mm/min. This value served as reference to adjust to zero the friction inherent to the experimental model before starting each test.

Maximum friction values and friction values at 6 mm of elevation of the maxillary canine bracket (static friction) were both calculated for all tests performed on each group. Tests were performed in dry conditions and room temperature at $25 \pm 2^\circ\text{C}$.

To eliminate a potential performance bias associated with bracket fatigue, the first sequence in which the groups were tested was randomly established. The following sequences were determined by a combinatorial analysis.

Data were collected and stored into SPSS (Statistical Package for the Social Sciences, SPSS Inc, Chicago, USA, version 10.0 for Microsoft Windows), and submitted to statistical analysis. The evaluation of sample distribution was carried out by the Shapiro-Wilk test at 5%, in order to detect normal distribution.

The means, standard deviation and confidence interval at 95% were obtained for maximum friction and for friction at 6 mm produced on each group. Intergroup comparison was carried out by one-way ANOVA with level of significance set at 5%. Bonferroni test with the same level of significance was used to determine potential statistical differences between paired groups.

RESULTS

Descriptive analysis and intergroup comparison are available for friction at 6 mm (Table 1) and maximum friction (Table 2).

For both types of friction, ANOVA detected statistically significant difference between groups (friction at 6 mm: $P = 0.000$; maximum friction: $P = 0.000$).

Paired group comparisons performed for friction at 6 mm (Table 1) resulted in no statistically significant difference between the control and CAP groups ($P = 0.396$). Friction presented by the TRP group was statistically higher than those of the control ($P = 0.000$) and CAP ($P = 0.000$) groups.

With regard to maximum friction (Table 2), no statistically significant difference was found between the control and the CAP group ($P = 0.340$). TRP friction was statistically higher than friction produced by the control ($P = 0.000$) and by the CAP ($P = 0.000$) group.

Table 1 - Descriptive analysis and intergroup comparison for friction at 6 mm.

Group	n	Mean (Newtons)	Standard-deviation (Newtons)	Confidence interval at 95%
Control (6 mm)	21	7.67 ^A	0.59	7.39 – 7.94
CAP (6 mm)	21	8.10 ^A	0.64	7.79 – 8.37
TRP (6 mm)	21	9.90 ^B	1.23	9.90 – 9.34

Different letters represent statistically significant difference between groups ($P \leq 0.05$).

Table 2 - Descriptive analysis and intergroup comparison for maximum friction.

Group	n	Mean (Newtons)	Standard deviation (Newtons)	Confidence interval at 95%
Control (maximum friction)	21	7.97 ^A	0.58	7.70 – 8.23
CAP (maximum friction)	21	8.29 ^A	0.60	8.01 – 8.56
TRP (maximum friction)	21	10.20 ^B	1.28	9.61 – 10.79

Different letters represent statistically significant difference between groups ($P \leq 0.05$).

DISCUSSION

For a 6-mm crowded maxillary canine, CAP data were not higher than data from the control group (unprotected brackets). This magnitude of canine crowding was regarded as severe in previous reports.¹⁵ Even under such circumstances, the fabricated customized acetate protectors produced a friction quite similar to that seen in conventional systems, in which no protection is employed.

We believe that such result was obtained because of careful protector fabrication in which any contact between the acetate, the wire and the slot was fully avoided. Another literature report published in 2009¹⁰ tested the friction level produced by an elastic ligature of which design also intended to avoid any type of contact with both the wire and the bracket slot. Similar to what we observed with our customized acetate protector, the authors also reported a lower friction degree of their elastic ligatures in comparison to conventional ligatures. Such tendency in reducing the friction degree when using either special ligatures^{8,11,15,16} or passive self-ligating brackets^{17,18} has been shown in the literature.

It is also important to bear in mind that contact between different materials collaborates to increase friction. A previous study¹² tested a system in which all components were metallic: the wire, the ligature and the slot. This scenario yielded a decrease in friction similar to what is seen with self-ligating brackets. The acetate protectors used in the present study went through a very careful fabrication process focused on avoiding any contact between the protector and the other components of the system. This measure was particularly reinforced at the level of bracket slot entrances.

Because friction increases as wire thickness increases,¹⁹ it would have been interesting if rectangular wires had been tested as well. However, soft tissue protectors are mostly needed during the initial phases of orthodontic treatment (leveling and alignment). For this reason, a superelastic round wire seemed to be more appropriate to simulate the correction of a blocked maxillary canine. The chosen diameter of 0.014-in was based on a study⁸ in which the same type of malocclusion was simulated. Nevertheless, instead of calculating the mean of all frictions produced at several points along the 6 mm of correction, we decided to assess the greatest friction therein produced (maximum friction). Because of the large number of points along 6 mm of misalignment, and also due to the expected low values in Newton (N), the maximum friction appeared to be more representative of the obstacle to tooth movement.

In contrast to the methodology previously described,¹⁴ the 19 mm inter-bracket distance was reduced to 6 mm in order to be more in line with clinical reality. In the present study, only the wires and ligatures were changed in between tests, differently from previously published studies,¹⁴ in which brackets, wires and elastic ligatures were changed every five tests. We considered bracket replacement to be a disadvantage, since their replacement could increase the odds of standardization error. We also believe that the random order in which the groups were tested might have solved the bias related to bracket fatigue.

In addition to the improved level of comfort that patients are likely to experience with this customized acetate

protector, the findings of the present study suggest that it does not interfere in orthodontic mechanics. As the tested protector does not seem to increase friction, it is believed that it may not interfere in treatment time, although treatment time does not seem to be solely dependent on friction, but also on the binding of the wire against the corners of the bracket.⁶ Nevertheless, we must bear in mind that such a problem is more common during sliding mechanics, not during leveling of canines as it is the case illustrated here.

When it comes to clinical feasibility, we do not expect clinicians to manufacture every single protector for their patients. Instead, we expect the orthodontic industry to manufacture kits of protectors that fit their different bracket designs. As long as the principles described here are incorporated into the industrialization process in a standardized manner, there shall be no concerns regarding technique sensitivity.

Although RCT studies conducted to evaluate the level of comfort of the acetate protectors are indeed necessary, the authors are confident in terms of

material stability under the harsh conditions of the oral environment. The proposed acetate protectors can only increase friction if they shrink in contact with saliva. However, this seems to be highly unlikely as this is a material that is prone to absorb rather than lose components. On the other hand, virtually all composite materials undergo polymerization shrinkage, thereby increasing the chances of friction between the wire and the bracket slot.

In the future, it seems appropriate to carry out similar studies using thicker wires in order to simulate space closure mechanics. *In vitro* biosafety and temperature tests must also be conducted.

CONCLUSION

It was possible to conclude that the use of an acetate bracket protector, such as proposed in the present *in vitro* study, results in a friction level similar to that observed with unprotected brackets. An opposite outcome was obtained when using a temporary resin as a form of protection to soft tissues.

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Microscopic evaluation of induced tooth movement after subluxation trauma: an experimental study in rats

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Objective: The objective of this study was to assess the histological alterations that occurred in the periodontal area of rat molars submitted to induced tooth movement (ITM) right after an intentional trauma (subluxation).

Methods: Forty adult male Wistar rats (*Rattus norvegicus albinus*) were selected. The animals were divided into eight groups (n = 5), according to the combination of variables: Group 1 – control (neither trauma nor ITM); Group 2 – ITM; Groups 3, 4, 5 and 6 – dentoalveolar trauma groups corresponding, respectively, to 1, 3, 8 and 10 days after trauma; Groups 7 and 8 – the animals' molars were subjected to a 900 cN impact and, one and three days after the trauma event, tooth movement was induced. The rats' maxillary first molars were mesially moved during seven days with a closed coil (50 cN). After the experimental period of each group, the animals were sacrificed by anesthetic overdose and the right maxillas were removed and processed for histological analysis under light microscopy.

Results: In the animals of group 3, 4, 5 and 6, the histological alterations were not very significant. Consequently, the effect of induced tooth movement right after a subluxation event (groups 7 and 8) was very similar to those described for Group 2.

Conclusion: There was no difference in the quality of periodontal repair when ITM was applied to teeth that had suffered a subluxation trauma.

Keywords: Orthodontics. Tooth injuries. Periodontium.

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INTRODUCTION

According to the classification of the World Health Organization (WHO),¹ dentoalveolar trauma may affect the teeth, supporting tissues, gingiva and the oral mucosa. From an orthodontic point of view, the main concern is about trauma caused to the periodontal tissues, including the alveolar bone, periodontal ligament and root cementum. This is because the success of orthodontic therapy depends on the normality of these tissues, since tooth movement is directly associated with the supporting periodontium.²⁻⁵

Subluxation is the most common trauma that affects the supporting periodontium, representing one fourth of all traumas that involve injury to the periodontal ligament.⁶ In subluxation, the tooth is not displaced from its initial position, and after trauma it will have a certain degree of mobility.¹

After subluxation trauma, the histological events involve, in the first few hours, hemorrhage in the periodontal ligament space, lesion in periodontal fibers and cell death. Afterwards, hyalines and inflammatory mediators, which induce bone and root resorption, will appear. Ten days after trauma, with less concentration of inflammatory products, periodontal repair begins.^{1,7}

The protocols of the International Association of Dental Traumatology,^{8,9,10} disclosed in 2007, present a consensual view of several researchers and clinicians from different specialties about the care and procedures performed in traumatized teeth. This guide suggests treatment procedures for different types of traumatism, indicating that in the event of subluxation, there is no need for specific treatment and the involved teeth must be followed-up for at least three months before being submitted to orthodontic forces.^{8,9,10} This is the current paradigm with regard to subluxated teeth: orthodontic force is considered an additional trauma to the periodontium, thus, the professional must be cautious when recommending it.¹¹

In opposition to the state of the art with regard to movement of traumatized teeth, other authors suggest that movement of luxated teeth may relieve the areas of compression in the periodontium and pulp, and, therefore, facilitate the repair of these tissues.^{3,12} As a secondary consideration, Mine et al³ inferred that calculated mechanical stimuli, such as orthodontic forces, would be important so that after injury, the process of

migration and proliferation of periodontal ligament cells would occur, preventing the occurrence of ankylosis and inflammatory root resorption.

Nevertheless, the real histological effect of applying an orthodontic load on a recently traumatized tooth has not been experimentally established.^{1,13-16} Furthermore, the relationship between time and the movement of a traumatized tooth also needs to be experimentally established for the periodontal tissues. In other words, there is a lack of scientific evidence to support the clinical procedures.⁵

Thus, this study assessed the histological alterations that occurred in the periodontal tissue of rat molars submitted to induced tooth movement (ITM) right after an intentional trauma (subluxation).

MATERIAL AND METHODS

The research project was independently reviewed and approved by the Animal Research Ethics Committee of the School of Dentistry of Araçatuba, State University of São Paulo (UNESP, Brazil). All guidelines regarding the care of animals used during research were strictly followed.

Forty male Wistar rats (*Rattus norvegicus albinus*) weighing between 250 and 350 g were selected for the study. The animals were housed in plastic cages under controlled climate conditions (12h light / 12h dark; thermostatically regulated room temperature), were fed with standard solid food (Ração Ativada Produtor; Anderson & Clayton S.A. Indústria e Comércio, São Paulo/SP, Brazil) and water *ad libitum*.

All experimental procedures were performed under anesthesia. The animals received an intramuscular injection of xylazine hydrochloride (Dopaser®; Caleir S.A., Barcelona, Spain; 0.03 ml/100 g body weight) and ketamine hydrochloride (Vetaset®; Fort Dodge Animal Health, Overland Park, KS, USA; 0.07 ml/100 g body weight).

The animals were divided into 8 groups (n = 5). In Group 1 (control group — normal periodontium), animals were monitored throughout the whole experiment without induction of any treatment. After the experimental period, they were submitted to euthanasia. In Group 2 (induced tooth movement group), a device used to induce tooth movement was placed in the animals, and after seven days of movement the animals were submitted to euthanasia.

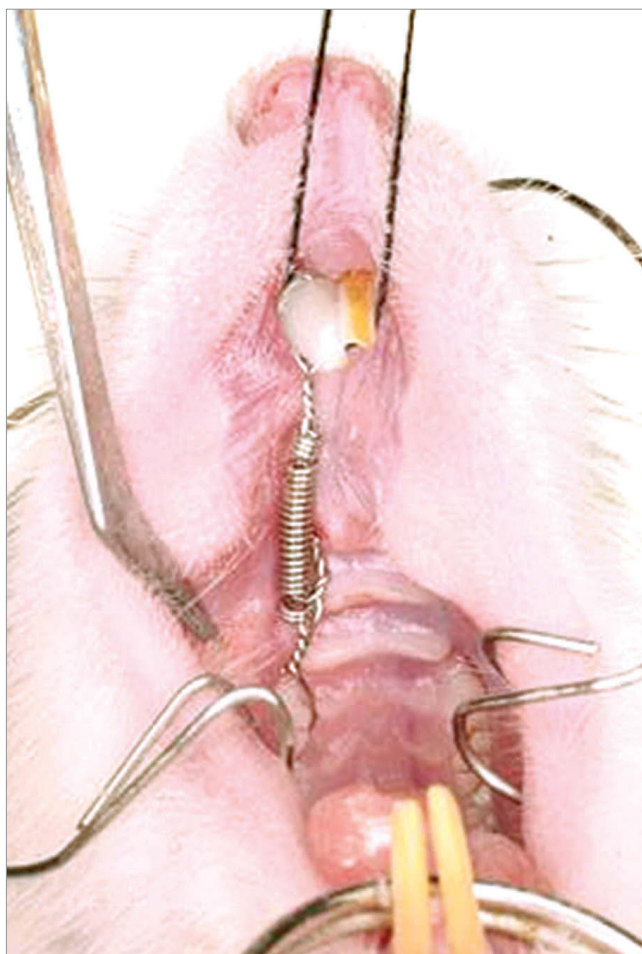


Figure 1 - Tooth movement device proposed by Heller and Nanda.¹⁷ Extended coil (50 cN).

In Groups 3, 4, 5 and 6 (trauma groups corresponding, respectively, to 1, 3, 8 and 10 days after trauma), the animals received an intentional dentoalveolar trauma on the occlusal surface of the maxillary first molar and after time intervals of 1, 3, 8 and 10 days, respectively, they were submitted to euthanasia. In Group 7 (one-day movement trauma group), a device used to induce tooth movement was placed one day after dentoalveolar trauma, and after seven days of movement, the animals were submitted to euthanasia. In Group 8 (three-day movement trauma group), a device used to induce tooth movement was placed three days after dentoalveolar trauma, and after seven days of movement, the animals were submitted to euthanasia.

In the groups of animals submitted to induced tooth movement (Groups 2, 7 and 8), a device similar to the model proposed by Heller and Nanda¹⁷ (Fig 1) composed of a closed section coil (Morelli, Sorocaba, São Paulo, Brazil - code 35.20.061) and two 0.25 mm wire ligatures (Morelli, Sorocaba, São Paulo, Brazil - code 55.01.210) were placed on the right maxillary first molar in order to promote molar mesial movement by applying controlled force of 50 cN, measured with the aid of a tensiometer (Zeusan Exporting Ltda Campinas, São Paulo, Brazil).

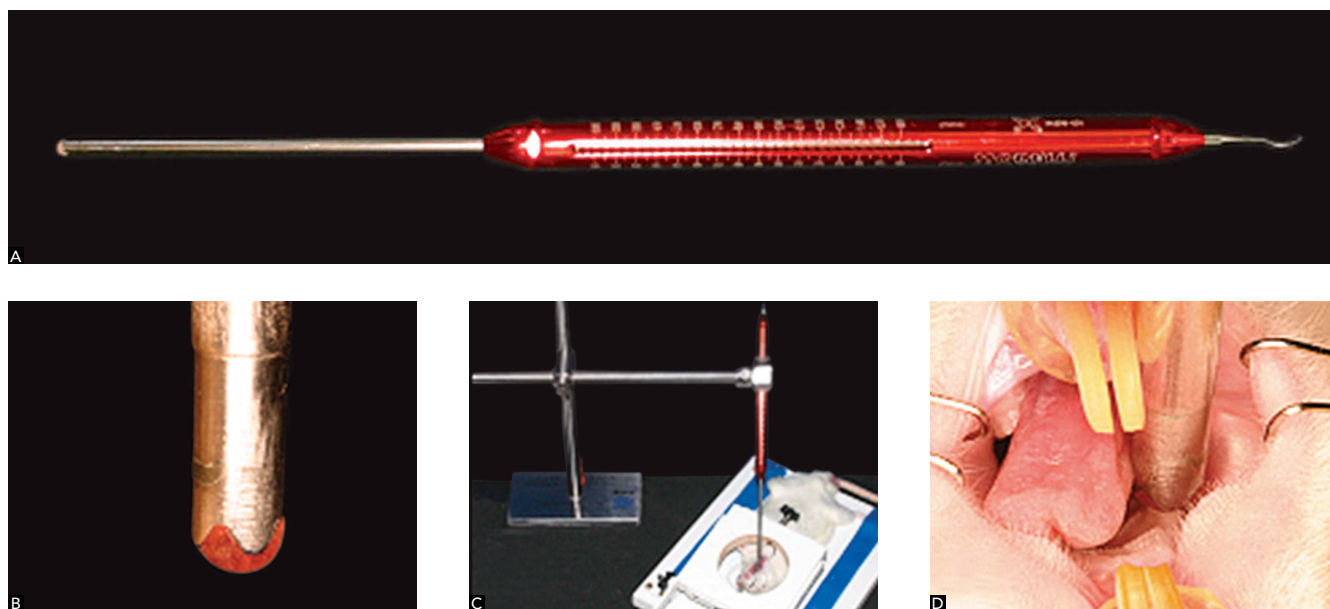


Figure 2 - Device used to promote experimental dentoalveolar trauma: A) Tensiometer used to assess the load. B) Tensiometer active tip adapted with acrylic resin. C) Tensiometer properly adjusted to the rat's molar. D) Tensiometer extremity adjusted to the vestibular crest of the right maxillary first molar.

Animals in the groups submitted to dentoalveolar trauma (Groups 3, 4, 5, 6, 7 and 8) received a standardized impact of 900 cN directed to the occlusal surface of the right maxillary first molar using an adapted tensiometer (Morelli, Sorocaba, São Paulo, Brazil - code 75.02.006) in order to maintain the same intensity and direction of force application, as described by Pereira et al¹⁸ (Fig 2).

Immediately after the experimental period of each group, the animals were sacrificed by anesthetic overdose through peritoneal injection. The right maxillas were removed, fixed in 10% buffered formalin for 24 hours and decalcified in 10% EDTA solution for 5 weeks. After decalcification, the specimens were embedded in paraffin and serial histological sections 6 µm thick were cut from the mesial root of the maxillary right first molar (including the surrounding tissues) in a longitudinal (mesiodistal) direction following the long axis of the tooth. For histological analysis, sections from the middle portion of the root were collected, stained with hematoxylin and eosin and observed under light microscopy (Carl Zeiss do Brasil Ltda., São Paulo/SP - Brazil). The areas in the cervical, middle and apical thirds of the mesial root of the first maxillary molar were selected for histological description under 73 and 170x magnification. The following tissues were considered for analysis: alveolar bone, cementum and periodontal ligament.

RESULTS

In Group 1 (with no trauma or movement), the periodontal ligament was rich in collagen fibers and fibroblasts. The collagen fiber bundles were disposed horizontally in the cervical region, while in the middle and apical thirds they were obliquely placed. In the peri-apical and furcation region, these fibers were irregularly disposed. Close to the apex, the dentin was covered by primary cementum which was covered by a thin layer of secondary cementum. The alveolar walls were rich in osteoblasts and osteocytes.

Animals submitted to dentoalveolar trauma only (Groups 3, 4, 5, 6) presented microscopic characteristics that were similar to Group 1, except for some animals showing points of superficial root resorption and some points of resorption in the alveolar walls, with osteoclasts near the resorbed area (Fig 3). In the animals submitted to induced tooth movement (Group 2), the root surface was intact throughout the entire extension of its mesial portion. A layer of cementoblasts-like cells was observed in the cementum that covers the root surface. Near this structure, the extremities of the collagen fibers of the periodontal ligament were found. In one specimen, small points of proximity between the cementum and the alveolar bone were found in the distal surface of the root only in the apical third. In all the specimens,

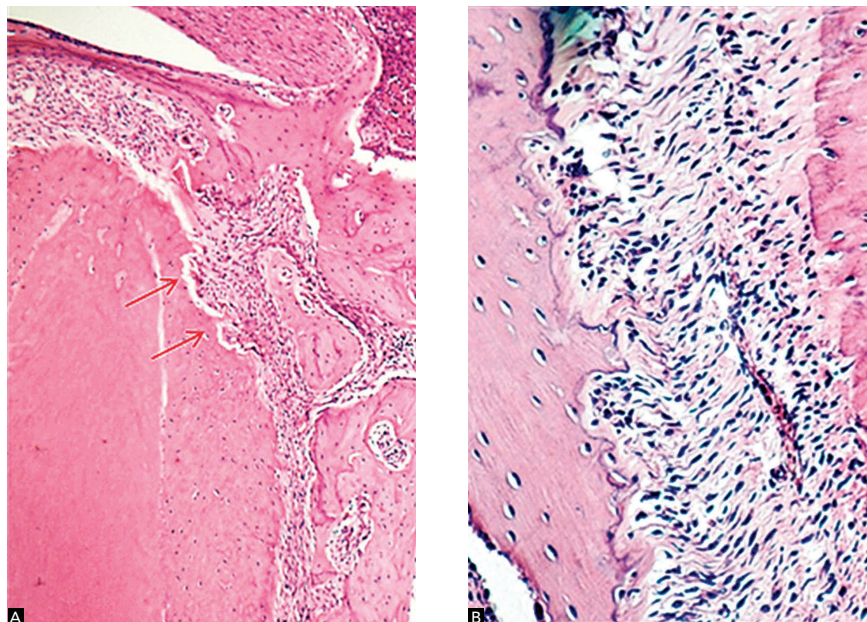


Figure 3 - Groups 5 and 6. **A)** Apical third of the distal surface of the root with surface cementum resorption (arrows) - mag. 63x. **B)** Alveolar crest. Active bone resorption, with the presence of clasts - mag. 160x.

the periodontal ligament was rich in collagen fibers and fibroblasts. In the cervical third of the mesial surface and in the apical third of the root, the fibers had no defined organization. In this region, an infiltrate of lymphocytes and histiocytes in the fibrous conjunctive tissue was also found in some specimens. In three specimens, some points of proximity between the cementum and the alveolar bone were found in the apical third of the distal surface of the root. In the other areas, the fibers were obliquely disposed and inserted in the cementum surface on one side and in the bone surface on the other. In the alveolar bone crest, some points of bone resorption were found in one specimen. In other specimens, these points were characterized by small bone cavities with no clasts and with neoformed bone tissue (Fig 4).

In Groups 7 and 8, corresponding to the teeth that were traumatized and moved one and three days after dentoalveolar trauma, the root surface on the mesial side was intact throughout its entire extension. A layer of cementoblasts-like cells was found in the cementum layer that covers the root surface. In five specimens from Group 7 and in two specimens from

Group 8, areas of surface resorption were found, especially in the apical portion on the distal side of the mesial root. In two specimens (Group 7), deeper areas of cementum-dentin resorption were found in the middle third on this side of the root. In one of them, an area of ankylosis was also detected in the middle third, and in two specimens, an area of hyaline degeneration was found, one in the mesial cervical region and another in the distal apical portion. Group 8 showed an area of greater proximity of the root surface to the alveolar bone wall in the apical third in three specimens. In this space, the presence of a small area of hyaline degeneration was found. In all specimens from Group 7 and 8, the periodontal ligament was rich in collagen fibers and fibroblasts. The fibers were obliquely disposed in comparison to the root surface, and were inserted into the cementum surface on one side and into the alveolar bone wall on the other. In four specimens from Group 7 and three from Group 8, several points of bone resorption were observed in the cervical third of the alveolar wall on the mesial side of the root. In the other areas, bone tissue was intact in its whole extension (Fig 5).

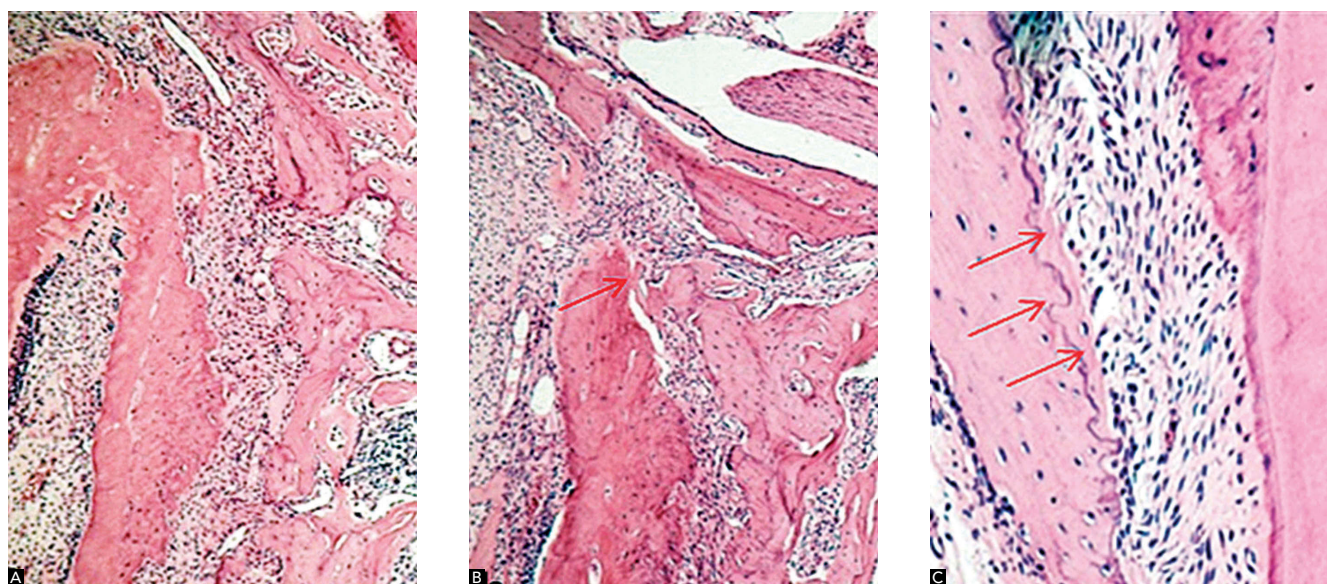


Figure 4 - Group 2. **A)** Apical third of the distal surface of the root with periodontal ligament (fibroblasts and collagen fibers) irregularly disposed - mag. 63x. **B)** Points of contact between root and alveolar surfaces in the apical third of the distal surface of the root (arrow) - mag. 63x. **C)** Alveolar crest with neoformed bone tissue (arrows) - mag. 160x.

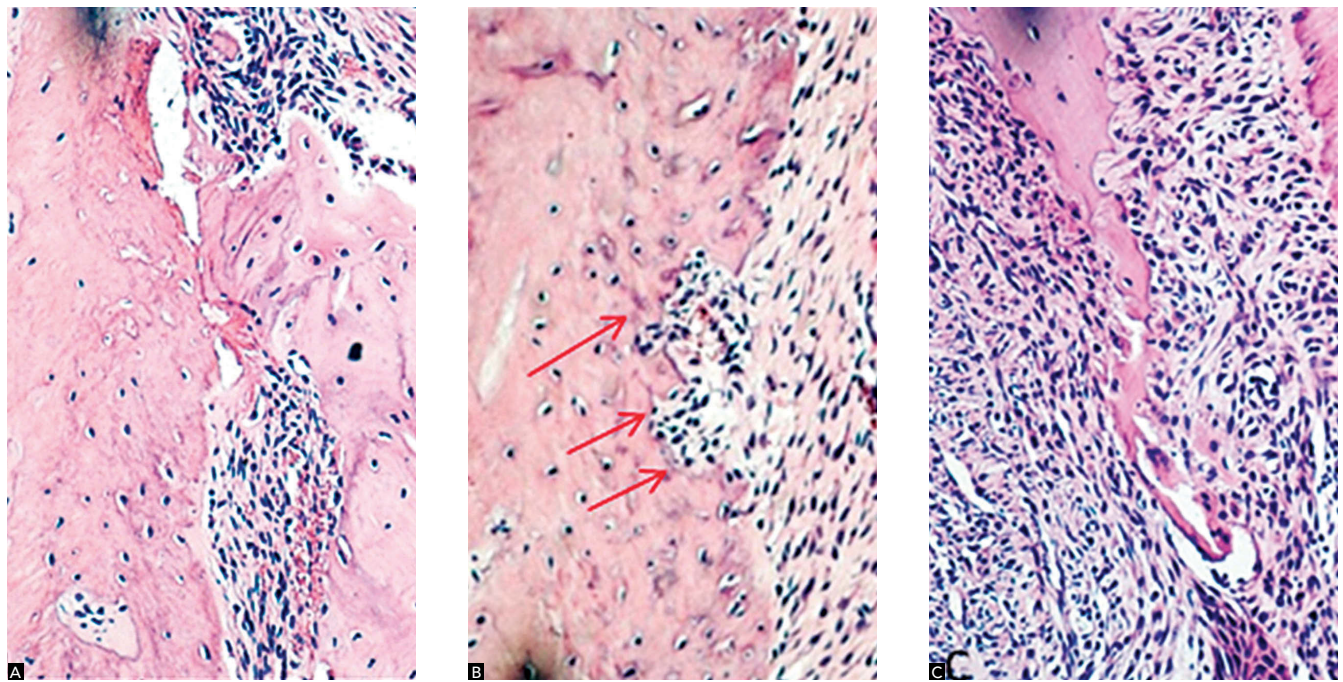


Figure 5 - Groups 7 and 8. **A)** Apical third of the root, hyaline areas - mag. 160x. **B)** Points of root resorption (middle third of the root - arrows) - mag. 160x. **C)** Fracture of the alveolar crest and osteoclasts - mag. 160x.

DISCUSSION

The characteristics of tissues under induced tooth movement in normal rats have been widely studied and the morphological features described were similar to those seen in human teeth.^{19,20,21} Conversely, descriptions of the aspects of induced tooth movement in teeth under the influence of periodontal trauma are rare.^{22,23,24}

Turley et al^{22,23} and Gomes et al²⁴ induced movement of traumatized teeth. They worked with an experimental model comprising dog premolars and incisors with more severe levels of trauma (intrusive luxation). The option of studying subluxation was based on the fact that this type of trauma is very prevalent among injuries of the periodontal ligament.⁶ Furthermore, despite the fact that the histological events after luxation have been widely described in the literature, there is a lack of studies with regard to how repair occurs in cases of subluxated teeth.

Therefore, with respect to the periodontal ligament of the assessed groups, a similarity between the architectural organization of the periodontal fibers in the dento-alveolar trauma groups (Groups 3, 4, 5 and 6) and in the normal periodontium group (Group 1) was observed, thus showing that the magnitude of the trauma applied

can be considered light. With regard to the groups that received orthodontic movement, either in the presence (Groups 7 and 8) or absence of trauma (Group 2), a similarity in the microscopic events was also observed with absence of a definite organization of collagen fibers, and presence of signs of inflammatory events, especially in the mesial cervical region and distal apical portion of the root. This probably occurred because, in these areas, the periodontal ligament is compressed during molar inclination as a result of tooth movement.

Although there have been divergences with regard to experimental time, type of trauma and the fact that the tooth movement inducing device was reactivated, Turley et al²³ observed that in the teeth that suffered slight intrusions (0.5 to 1 mm) and were orthodontically extruded afterwards, inflammatory root resorption occurred and this result was similar to Groups 7 and 8 of this study, in which points of surface resorption were observed in seven out of ten animals, particularly in the apical portion of the distal side of the mesial root that was an area of periodontal ligament compression. These results of superficial and inflammatory root resorption were also detected in the groups of animals submitted to

dentoalveolar trauma (Groups 3, 4, 5 and 6), although in limited areas and of less magnitude. Deeper areas of cementum-dentin resorption were also found in the middle thirds of the root of two specimens from Group 7, whereas in one of them, an area of proximity between the cementum and the alveolar bone was found. Gomes et al²⁴ also found similar results in dogs. They observed extensive lacunar resorption that reached the dentin, mainly in the cervical third, but with great repair activity and no evidence of active root resorption. In the induced tooth movement group (Group 2), areas of proximity were also found between the cementum and the alveolar bone in the apical third of the distal surface of the root. It seems that the contact between the cementum and the alveolar bone in Groups 7 and 8 is more related to induced tooth movement than to the effect of the trauma, since those events were also observed in Group 2. This aspect was not found in the groups submitted to trauma (Groups 3, 4, 5 and 6).

As found by Turley et al²² and Gomes et al²⁴, areas of bone resorption with the presence of multinucleated cells in the Howship lacunae were also observed in seven specimens from Groups 7 and 8. In the group submitted to induced tooth movement (Group 2), the same resorption lacunae were also found. Once

again, when trauma was associated with movement (Groups 7 and 8), the events of alveolar bone wall repair were similar to those of Group 2.

Considering the histological events of the supporting periodontium after subluxation trauma and induced tooth movement, there seems to be no objective reasons to wait after this type of trauma to start orthodontic treatment. The hyalinization of the periodontal ligament as well as the root and bone resorptions observed were similar in the induced tooth movement groups (Groups 2, 7 and 8) in such a way that the application of a controlled orthodontic force on a tooth that suffered subluxation trauma is not contraindicated. In other words, under the experimental conditions of the present study, the follow-up time of a traumatized tooth recommended by the literature,^{6,8,9,10} before orthodontic movement is induced, does not seem to be true in the case of teeth that suffered subluxation.

CONCLUSION

Based on the methods and the results of this study, it is reasonable to conclude that there was no difference in the quality of the periodontal tissue response when induced tooth movement was applied in one and three days after an event of subluxation.

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Comparative photoelastic study of dental and skeletal anchorages in the canine retraction

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Objective: To compare dental and skeletal anchorages in mandibular canine retraction by means of a stress distribution analysis.

Methods: A photoelastic model was produced from second molar to canine, without the first premolar, and mandibular canine retraction was simulated by a rubber band tied to two types of anchorage: dental anchorage, in the first molar attached to adjacent teeth, and skeletal anchorage with a hook simulating the mini-implant. The forces were applied 10 times and observed in a circular polariscope. The stresses located in the mandibular canine were recorded in 7 regions. The Mann-Whitney test was employed to compare the stress in each region and between both anchorage systems. The stresses in the mandibular canine periradicular regions were compared by the Kruskal-Wallis test.

Results: Stresses were similar in the cervical region and the middle third. In the apical third, the stresses associated with skeletal anchorage were higher than the stresses associated with dental anchorage. The results of the Kruskal-Wallis test showed that the highest stresses were identified in the cervical-distal, apical-distal, and apex regions with the use of dental anchorage, and in the apical-distal, apical-mesial, cervical-distal, and apex regions with the use of skeletal anchorage.

Conclusions: The use of skeletal anchorage in canine retraction caused greater stress in the apical third than the use of dental anchorage, which indicates an intrusive component resulting from the direction of the force due to the position of the mini-implant and the bracket hook of the canine.

Keywords: Orthodontics. Tooth movement. Orthodontic anchorage. Procedures.

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INTRODUCTION

The concern over anchorage has always accompanied the evolution of Orthodontics. Many resources have been used with the purpose of avoiding undesired movement of the anchoring unit, namely: headgear appliances, lingual arches and transpalatal bars. Some approaches to anchoring consider the biological basis and avoid mobility of posterior teeth before space closure. In these cases, rigid appliances are combined with monitoring of the occlusion in order to achieve anchoring.¹ Strategies such as including the second molar in the mechanics, using low forces for retraction and low friction mechanics have already been suggested to minimize loss of anchorage.² Despite the availability of several papers studying anchorage, due to methodological issues, the scientific evidence is not considered sufficient to identify the most effective anchoring system.³

When maximum anchorage is needed to achieve the proposed objectives, mini-implants have been adopted to replace dental anchorage. The efficiency of mini-implants in controlling loss of anchorage has been confirmed in a study⁴ that identified average anchorage loss of 1.6 mm in the maxilla and 1.7 mm in the mandible on the side where canine retraction was anchored in the molar, and no loss on the side with mini-implants. Skeletal anchorage has also been named absolute anchorage;^{5,6} however, some researchers have questioned this nomenclature because mini-implant movement and loss of anchorage have been identified even with the use of skeletal anchorage.^{7,8}

Skeletal anchorage can be used in a direct or indirect manner. The indirect one does not influence the vector systems of the forces employed, however, if the mini-implant moves, it might result in loss of anchorage of the involved teeth. This possibility does not exist in direct anchorage; however, the location of mini-implants will directly influence the result of retraction movement. The terms high-pull or high installation (distance greater than 10 mm from the mini-implant to the orthodontic arch), medium-pull (8 to 10 mm) and low-pull (<8 mm)⁹ are appropriate for the maxilla, but difficult to interpret when referred to the mandible. Therefore, it has been suggested that the force vectors be described as intrusive, intermediate and extrusive according to their effect on the anterior region.¹⁰

As for issues concerning biomechanics, especially magnitude and direction of the force employed to retract

the canines, the proposed hypothesis is that the force vector resulting from direct skeletal anchorage would have a more vertical direction due to the mini-implant being inserted more apically than the molar hook used for dental anchorage. Additionally, it is also due to the fact that the canine hook is positioned closer to the occlusal surface than the mini-implant is, even though the mini-implant is inserted as close as possible to the cervical region. This situation would probably result in an intrusive effect associated with the retraction movement accompanying the use of skeletal anchorage.

Therefore, the present study compared dental and skeletal anchorage in mandibular canine retraction by means of stress distribution analysis performed in the periradicular region of the tooth with the use of a photoelastic model.

MATERIAL AND METHODS

A photoelastic model was built from the mandibular second molar to the canine without the first premolar in order to simulate its extraction. Initially, bands and frictional brackets, Roth prescription (Ovation/Dentsply GAC International, Bohemia, NY, USA) were bonded to the artificial teeth (B2-306/Kilgore-Nissin; Kilgore International, Coldwater, MI, USA) and a 0.021 x 0.025-in stainless steel wire ("A" Company, San Diego, CA, USA) was installed.

This set was positioned in a rectangular (30 x 50 x 10 mm) silicone mold (Polipox, São Paulo, Brazil) filled with GIII flexible epoxy resin (Polipox). The set was then transferred to a vacuum chamber (-600 mm Hg) in order to have air bubbles eliminated. After 30 minutes, the photoelastic model was removed from the vacuum chamber. Tests were conducted 72 hours later. The 0.021 x 0.025-in stainless steel wire was replaced by a segment of 0.019 x 0.025-in ("A" Company, San Diego, CA, USA) stainless steel wire.

As for dentoalveolar anchorage, teeth from second molar to second premolar were splinted with metallic ligature (0.25 mm, Morelli, Sorocaba, SP, Brazil), and the hook of the first molar was used as a support for the application of force for canine retraction.

To simulate skeletal anchorage, a hook was bonded to a metallic post attached to a metallic base used to avoid deflection. The model was bonded in such a way that the simulated mini-implant (hook) was positioned between the first molar and the second premolar,

8 mm away from the arch. The forces were applied 10 times to the photoelastic model, under two anchorage conditions: in the first molar attached to the adjacent teeth, and simulating the mini-implant. A dynamometer (Correx 250; Haag-Streit, Berne, Switzerland) was used to certify that all rubber bands (Morelli, Sorocaba, SP, Brazil) activations had a retraction force of 100 cN.

The model was observed by means of a circular polariscope (Eikonal Instrumentos Ópticos, São Paulo, Brazil) assembled with the following components: light source (Photoflood 2), diffuser, polarizer, quarter wave plate, photoelastic model, quarter wave plate and polarizer (analyzer)¹¹ (Fig 1). The circular polariscope was set up in a dark field, that is, the optical axes of the polarizer and the analyzer crossed to each other while the quarter wave plates crossed to each other at an angle of 45° with the polarizer and the analyzer.¹² The photographic machine (D70 Nikon, Melville, NY, USA) was positioned in front of the analyzer and its settings remained throughout the experiment. The photoelastic model was positioned in a rotating platform previously marked to facilitate accurate placement of the model. The model was observed in the polariscope before forces were applied with the objective of verifying the absence of residual stress in the material. After force application, pictures were taken from the side view.

The fringe orders were verified around the canine, considering the sequence of colors produced in photoelastic material submitted to the increasing application of load and observation in the dark-field white-light polariscope (Table 1).¹² It is possible to observe that values of

fringe order and of relative delay increase with stress.

The absence of stress is shown in Figure 1A, while stress distribution associated with dental anchorage and skeletal anchorage is shown in Figures 1B and 1C, respectively.

Statistical method

The significance level was set at 5% and adopted for all statistical tests. The error of the method was conducted to determine intra and interobserver agreement, for which the weighted kappa statistics was used. Ten photos from each group were reanalyzed by the same observer and by a second observer as well. To compare both types of anchorage, the Mann-Whitney test was used in each area evaluated, whereas to compare the stress between the periradicular regions of the canine, the Kruskal-Wallis test was used in each type of anchorage.

Table 1 - Sequence of colors produced in a dark-field white-light polariscope. Source: ASTM D4093-95 (reapproved 2001) and www.vishay.com.

Color	Relative delay (δ) Nm	Fringe order δ/λ
Black	0	0
Gray	160	0.28
White	260	0.45
Light yellow	350	0.60
Orange	460	0.79
Intense red	520	0.90
Red-blue transition	577	1.00
Intense blue	620	1.06
Blue-green	700	1.20
Green-yellow	800	1.38
Orange	940	1.62
Pinkish red	1050	1.81
Red-green transition	1150	2.00
Green	1350	2.33
Green-yellow	1450	2.50
Red	1550	2.67
Red-green transition	1730	3.00
Green	1800	3.10
Pink	2100	3.60
Pink-green transition	2300	4.00
Green	2400	4.13



Figure 1 - Circular polariscope.

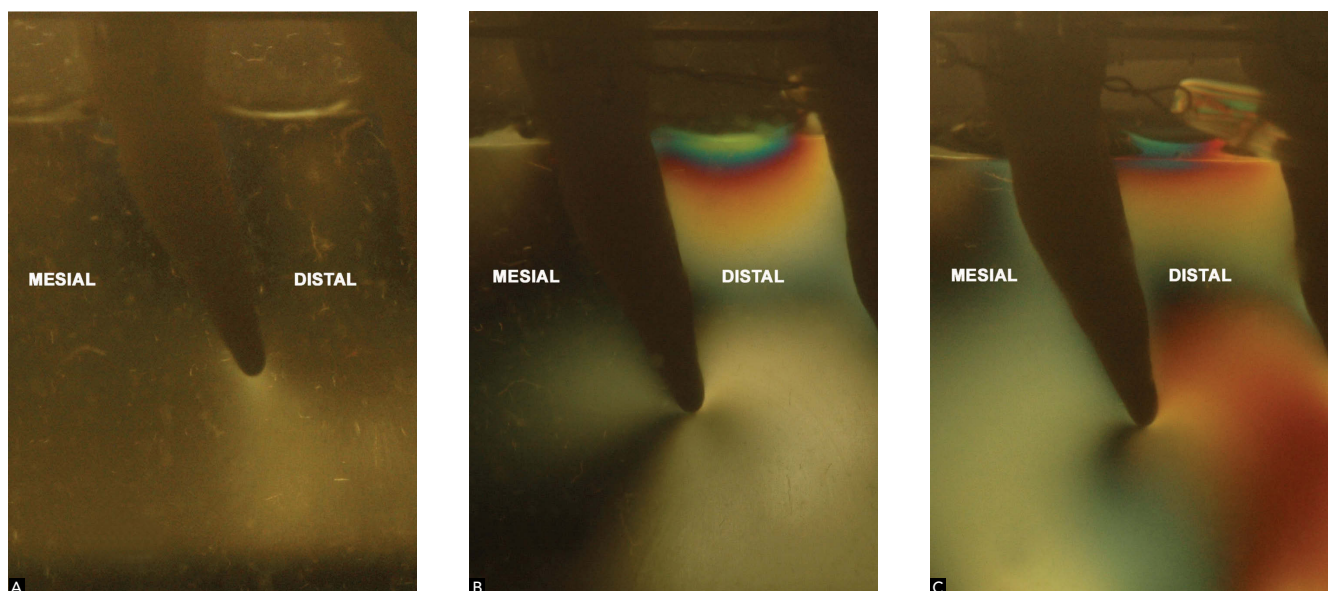


Figure 2 - Visualization of stress in dark-field circular polariscope: **A)** absence of stress; **B)** stress distribution with dental anchorage and **C)** stress distribution with skeletal anchorage.

RESULTS

The reliability of the values was confirmed by the error of method. The weighted kappa coefficients indicated that the agreements ranged from substantial to perfect. In the skeletal anchorage group, the coefficient ranged from 0.61 to 1.0 in the intraobserver, while it ranged from 0.61 to 0.88 in the interobserver analysis. In the dental anchorage group, the weighted kappa coefficients ranged from 0.61 to 1.0 in the intraobserver and from 0.61 to 0.78 in the interobserver analysis.

Table 2 shows the values of the median, first and third quartiles of the isochromatic fringe orders located in the canine radicular third in 7 regions: cervical-mesial (CM), cervical-distal (CD), middle-mesial (MM), middle-distal (MD), apical-mesial (AM), apical-distal (AD), and the apex (A). The Mann-Whitney test (with a significance threshold set at $P < 0.05$) was employed to compare the fringe orders in each region, considering both anchorage systems. The stresses on the cervical and middle third were similar ($P > 0.05$). In the apical third, the stresses associated with skeletal anchorage (medians: AM = 0.6, AD = 1.0, and A = 0.9) were significantly higher than the stresses associated with dental anchorage (medians: AM = 0.45, AD = 0.79, and A = 0.6) ($P < 0.05$).

Table 3 shows the comparison between the fringe orders originating from retraction force associated with the use of dental anchorage in the canine periradicular regions, which was performed via the Kruskal-Wallis test (significance at $P < 0.05$). Higher stress concentrations were identified in the cervical-distal (0.9), apical-distal (0.79) and apex (0.6) regions. The stresses in these areas did not differ, but were significantly higher than in the cervical-mesial (0.28), middle-mesial (0.28) and middle-distal (0) regions. In the apical-mesial region (0.45), the stress was lower than in the cervical-distal and apical-distal, however, it was not statistically different from the apical region stress.

Table 4 shows the comparison, via the Kruskal-Wallis test (significance set at $P < 0.05$), between the fringe orders in the canine periradicular regions originating from retraction force associated with the use of skeletal anchorage. The highest stresses were located in the apical-distal (1.0), apex (0.9), cervical-distal (0.79) and apical-mesial (0.6) regions. The stresses in these areas did not differ, but were significantly higher than in the cervical-mesial (0.28) and middle-distal (0) regions. In the middle-mesial region (0.28), the stress was lower than in the apical-distal (1.0), apex (0.9) and cervical-distal (0.79) regions, however, it did not statistically differ from the apical-mesial (0.6) region.

Table 2 - Median, first and third quartiles related to dental and skeletal anchorage, and results of Mann-Whitney comparisons between both groups in the areas evaluated.

Area	Dental anchorage			Skeletal anchorage			p-value
	Median	Q1	Q3	Median	Q1	Q3	
CM	0.28	0.28	0.28	0.28	0.28	0.28	>0.05
CD	0.90	0.79	0.90	0.79	0.79	0.90	>0.05
MM	0.28	0.28	0.28	0.28	0.28	0.28	>0.05
MD	0.00	0.00	0.00	0.00	0.00	0.00	>0.05
AM	0.45	0.45	0.45	0.60	0.60	0.60	0.0002
AD	0.79	0.79	0.90	1.00	0.90	1.06	0.0009
A	0.60	0.60	0.79	0.90	0.90	0.90	0.0003

CM = cervical-mesial, CD = cervical-distal, MM = middle-mesial, MD = middle-distal, AM = apical-mesial, AD = apical-distal, A = apex.

Table 3 - Results of Kruskal-Wallis test for comparison between the areas with dental anchorage.

Area	Dental anchorage		
	Median	Middle rank	
CM	0.28	20	C/D
CD	0.9	61.6	A
MM	0.28	20	C/D
MD	0	6.5	D
AM	0.45	35.5	B/C
AD	0.79	57.6	A
A	0.6	47.3	A/B

Capital letters differ in the vertical direction.

Table 4 - Results of the Kruskal-Wallis test for comparison between areas with skeletal anchorage.

Area	Skeletal anchorage		
	Median	Middle rank	
CM	0.28	19	C
CD	0.79	47.6	A
MM	0.28	20.1	B/C
MD	0	7.4	C
AM	0.6	35.9	A/B
AD	1	63.7	A
A	0.9	54.8	A

Capital letters differ in the vertical direction.

DISCUSSION

The method used to evaluate the effects of skeletal anchorage on orthodontic movements requires further research and development. In the present study, the hook attached to a metallic post assembled to a stand to which the model was bonded was an artifice that allowed the application of force and the simulation of skeletal anchorage (if the hook were simply bonded to the model, it could itself generate stress). The artifice adopted in this study is based on a research carried out by Nakamura et al¹³ who used a support external to the photoelastic model to simulate the application of distalization force to the mandibular molars anchored to mini-implants.

While the safest zone for the installation of mini-implants is located between the first and second molars in the mandible,¹⁴ the hook used to simulate the mini-implant positioned between the second premolar and the first molar in order to achieve direct skeletal anchorage.¹⁰

Generally, mini-implants are installed more apically than the molar hooks; therefore, retraction associated with direct anchorage of mini-implants tends to introduce a vector of force that is more intrusive than what is observed with the use of traditional mechanics.¹⁰ This statement is supported by the present study, given the fact that the use of skeletal anchorage promoted significantly higher stresses in the canine apical region than the use of dental anchorage. It is worth mentioning that since skeletal anchorage does not allow the dissipation of mechanical force during retraction, as it occurs in dental anchorage, it can justify the higher stress magnitude observed in the apical region where skeletal anchorage was used.

By using dental anchorage, the action line of the retraction force went farther from the center of resistance of the canine, which, in single-root teeth, is located at 33–42% of the distance between the alveolar crest and the root apex.¹⁵ Although there was no statistically significant difference between the types of anchorage in

the cervical-distal region, the isochromatic fringes in this region, with the use of dental anchorage (Figure 1B), confirm that the canine retraction force tends to distally tip the crown when traction is anchored on the molars, even if 0.019x 0.025-in wire and brackets with 7° of angulation are used. Inclination and extrusion of the canine occur in response to orthodontic wire deflection caused by distalization force and are also due to the inherent difficulty of the tooth in performing a genuine movement of radicular translation. Therefore, there was a distal tipping trend of the canine regardless of the anchorage system used. Conversely, as the force anchored in the mini-implant presented higher stress in the apical region, it is assumed that there was a greater control of that tipping and extrusion tendency (Fig 1C).

The intrusive component of force associated with the distalization force in skeletal anchorage, significantly increased the stress in the apical region in comparison to dental alveolar anchorage (Table 2; AM, AD, and A regions).

With the use of dental anchorage, as shown in Table 3, the highest stresses were identified in the cervical-distal region (0.9). This stress value, however, does not significantly differ from the stress in the apical-distal region (0.79) or in the apical region (0.6). The observation that there was also stress in the apical region, even with the use of dental anchorage, can be explained by

the type of bracket used in the canine. In Roth prescription brackets, the 7° angulation tends to transfer force to the apical region, especially in the distal face of the apex.

On the other hand, the use of skeletal anchorage, when comparing the stress between the canine periradicular regions, indicated that the highest stress magnitude was located in the apical-distal region (1.0), however, that value was not statistically significant different in relation to the apical (0.9), apical-mesial (0.6) and cervical-distal (0.79) regions (Table 4). Future photoelastic studies might simulate the different directions of traction, varying the positions of the mini-screws and also the height of the hook in the anterior region to compare the stresses generated by the different force systems.

Although satisfying results can be obtained with either skeletal or conventional anchorage, retraction with the use of mini-implants does not require patient collaboration,¹⁶ and it is undoubtedly an anchorage resource that is gaining followers in the orthodontic practice.

CONCLUSION

Using skeletal anchorage for retraction promoted greater stress in the apical third in comparison to dental anchorage, which indicates an intrusive component originating from the force direction that results from the position of the mini-implant and the canine bracket hook.

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Dental transposition of canine and lateral incisor and impacted central incisor treatment: A case report

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Introduction: Dental transposition and impaction are disorders related to ectopic eruption or failure in tooth eruption, which can affect child physical, mental and social development and may be difficult to be clinically solved.

Methods: We describe a case of transposition between the upper left canine and lateral incisor associated with impaction of the central incisor on the same side, in a 12-year-old patient. Conservative treatment involving surgical-orthodontic correction of transposed teeth and traction of the central incisor was conducted.

Conclusion: The option of correcting transposition and orthodontic traction by means of the segmented arch technique with devices such as cantilever and TMA rectangular wire loops, although a complex alternative, was proved to be esthetically and functionally effective.

Keywords: Impacted tooth. Ectopic tooth eruption. Corrective orthodontics.

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

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INTRODUCTION

Impaction is a condition in which complete tooth eruption is hampered by contact with another tooth.¹ It is characterized by dental absence in the arch after its usual period of eruption,² and its etiology may be related to general or local factors.³ General factors include endocrine disorders, febrile diseases, radiation, heredity and development factors that may alter the eruption trajectory of the tooth germ.⁴ Local causes include lack of space in the arch, trauma, blocking by supernumerary tooth and lack of coordination between the formation of permanent teeth and deciduous exfoliation.⁵

Impaction is twice as common in females⁶ and can occur with any teeth, but the most affected are the lower third molars, upper canines and upper third molars, upper and lower second premolars and upper central incisor.⁷ When the upper permanent incisors are impacted, there may be impairment in physical, psychological and social development of the child.⁸ After diagnosis, the therapeutic decision should prioritize tooth eruption.⁹

Conversely, tooth transposition, reported since the early nineteenth century, is described not only as a reversal of position between two teeth in the same quadrant of the dental arch, especially in relation to their roots; but also as the development or eruption of a tooth in a position normally occupied by a non-adjacent element.¹⁰ It is considered real or complete when the tooth is in fully exchanged position in the dental arch and its roots are parallel to the other teeth; and incomplete when the teeth involved are not in fully exchanged position.^{11,12,13} It is also more prevalent in females, in the upper arch, and of unilateral type.^{11,12,14} The upper permanent canine is the most involved tooth, transposing with the first premolar in 80% of cases and with the lateral incisor in 20%.¹² The causes of tooth transposition also involves general or local factors such as genetic factors with multifactorial causes of inheritance, dental anomalies (congenital absence of the lateral incisor, cone-shaped lateral incisor, rotations and hypodontia), migration of the developing tooth from its normal eruption path, root dilacerations, dental trauma and intervention in the development of the dental lamina.¹⁵

Early diagnosis of transposition in tooth development and impaction is essential, and greatly influences the prognosis.¹⁶ Depending on the exact position of the impacted incisor, orthodontic movement and positioning

in the dental arch can vary widely. During orthodontic mechanics, occlusal interference should be avoided and root resorption should be controlled by periapical radiography so that bone loss does not occur, specially in the buccal bone plate.¹⁵ Incisors that are horizontally inclined, in severe ectopic position or in real or complete tooth transposition are more difficult to treat. In cases of late diagnosis, orthodontic planning interferes not only in the decision of extracting impacted or transposed teeth, but also in the correction of the order of tooth position.^{11,12,15} Mechanical traction is preferred in the upper central incisors, but potential esthetic and periodontal problems may arise.¹⁷

Imaging tests are important aids in the diagnosis of these complications. They include the use of periapical, occlusal and panoramic radiographs or cephalograms,¹⁸ and, most recently, cone beam tomography.²³

The objective of this paper is to report the treatment of a patient with tooth transposition between canine and lateral incisor of the upper left side associated with impaction of the upper central incisor on the same side.

CASE REPORT

A 12-year-old, female, Caucasian patient arrived for evaluation accompanied by her guardian, with her initial documentation at hand and orthodontic appliance installed. She had been undergoing treatment for 2 years and 7 months. Her chief complaint was that her front tooth was not born and two teeth had been born in exchanged position. The person responsible for the patient presented a transfer letter in which the orthodontist suggested clinical crown recontouring of the upper left lateral incisor into canine and upper left canine into lateral incisor, in addition to extraction of the retained central incisor.

Clinical examination revealed that the patient had permanent dentition with Angle Class II malocclusion on the left side due to migration of the posterior superior segment to a more anterior position; Class I malocclusion on the right side; upper midline deviation to the left; absence of tooth #21 with bulging in the vestibular region just below the anterior nasal spine (ANS), lack of space for its eruption, and transposition between teeth #22 and 23 (Fig 1). New radiographic documentation was, then, requested.

Panoramic, occlusal and periapical radiographs as well as cephalograms revealed impaction of tooth #21.

Its root was fully formed (Fig 2) and had the coronal long axis in a more horizontal position between the middle and apical third of the adjacent teeth roots (Fig 3). Incomplete transposition between teeth #22 and 23 and image overlap of tooth #22 root apex and tooth #21 root were confirmed (Fig 4).

Once diagnosis had been completed, orthodontic-surgical conservative treatment was planned, although impaction of tooth #21 and transposition of teeth #22 and 23 represented unfavorable factors. Treatment plan included an attempt to correct transposition of teeth #22 and 23 and traction of tooth #21, which was accepted by the patient and her guardians.

The orthodontic procedures began by removing the appliance previously installed on both arches of the patient, since it was an appliance aimed at a different purpose. After removal and prophylaxis, new bands and weld of upper triple tube and lower double tube were prepared, in addition to cementing them on the upper and lower first molars (Fig 5). The upper arch was shaped with impression material for the fabrication of Hilgers auxiliary appliance. Thereafter, the fixed metal orthodontic appliance was set with 0.018 x 0.030-in slot in both arches, semi-arches of stabilization with blue 0.016 x 0.016-in Elgiloy wire on the lower right and left sides as well as on the upper right side, an utility arch (UA) in the lower arch, and, on the upper left side, a semi-arch with helicals for intrusion of tooth #13 with TMA 0.017 x 0.025-in wire, with intrusive force of 45 grams to attempt dental transposition (Fig 6). After two days, the Hilgers appliance was installed for upper left molar distalization and anchorage of the upper premolars on the same side, thus, avoiding extrusion (Fig 7). After eight months, the necessary upper molar distalization and canine intrusion were obtained. The Hilgers appliance was removed and a quad-helix appliance (QH) was installed with 0.90 mm stainless steel wire to anchor and maintain upper left molar distalization (Fig 8). Additionally, 0.014-in round nickel-titanium alloy (NiTi) archwire was installed for teeth alignment and leveling without inclusion of tooth #23.

Cortical anchorage was performed in the lower arch with UA, raise of bite with compound resin in the occlusal region of the lower molars and, after alignment and leveling, a 0.014-in stainless steel wire was installed. Then, mesialization of the upper left lateral incisor began to transpose it with the upper left canine by means

of an open nickel-titanium (NiTi) spring in the stainless steel wire between the upper left first premolar and upper left lateral incisor. A closed nickel-titanium spring 50g/f was placed from the upper left second premolar to the upper left canine for canine distalization. A semi-arch with rectangular 0.017 x 0.025-in stainless steel wire with 3/16-in medium elastic was also installed (Fig 9). After transposition was completed, alignment and leveling were performed with 0.014-in NiTi wire (Fig 10) up to the 0.016 x 0.016-in square stainless steel wire for better stabilization. An open steel spring was used between teeth #11 and 22 to keep the recovered space that would be occupied by tooth #21 (Fig 11). Afterwards, surgical exposure and bonding of the traction accessory were performed.

Closed flap was the surgical technique chosen for traction. After 10 days, the sutures were removed and traction of tooth #21 began with 0.014-in NiTi wire superimposed to the square stainless steel archwire with open spring, by applying low magnitude forces in order to prevent unwanted movement of the adjacent teeth (Fig 12). After eruption of the retained tooth, the button that was placed during surgery was removed and the bracket was positioned. New alignment and leveling were performed by inserting the tooth in the arch, starting with 0.014-in NiTi wire up to the 0.016 x 0.016-in steel square wire during a period of 9 months.

After thirty-nine months of active orthodontic treatment, the fixed orthodontic appliance was removed and the retainer was installed. For the upper dental arch, a fixed retainer was fabricated with 0.015-in Twist-flex wire from the left canine to the right central incisor, associated with a removable plate with continuous arch adapted to the buccal surfaces, from second molar to second molar, without occlusal interferences. As for the lower dental arch, a fixed lingual arch fabricated with 0.80 mm stainless steel wire was adhered to the lingual surfaces of lower canines, with light-cured resin (Fig 13). The case has been finalized and it is currently under clinical (Fig 14) and radiographic follow-up (Fig 15).

DISCUSSION

Tooth transposition is classified into complete and incomplete according to the position of the crowns, roots and apex of transposed teeth. In incomplete transposition, the apexes tend to remain in their original position, while only the crowns suffer transposition.^{11,12,13}

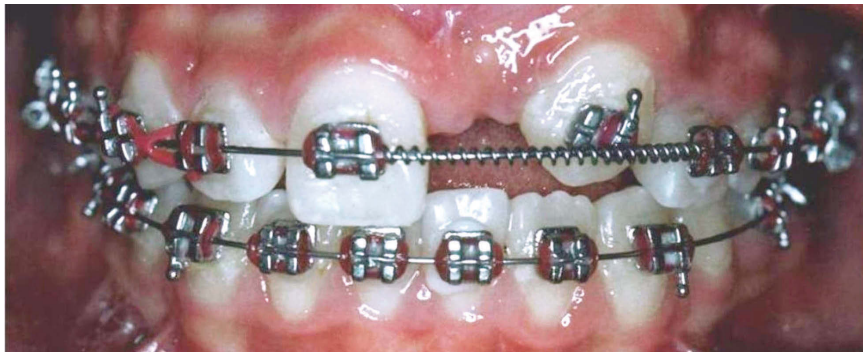


Figure 1 - Patient's initial photograph showing fixed appliance set with transposition between the upper left canine and lateral incisor, and the absence of upper central incisor on the same side.

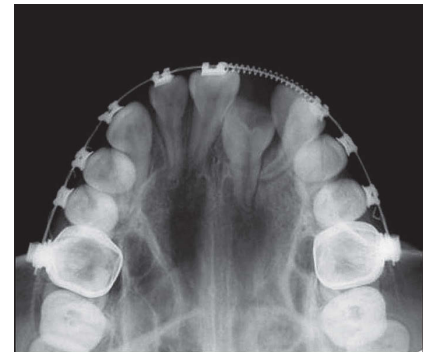


Figure 2 - Occlusal radiograph revealing impaction of tooth #21 with complete root formation.



Figure 3 - Lateral cephalogram revealing impaction of tooth #21 with coronal long axis horizontally positioned between the middle and apical third of adjacent teeth roots.

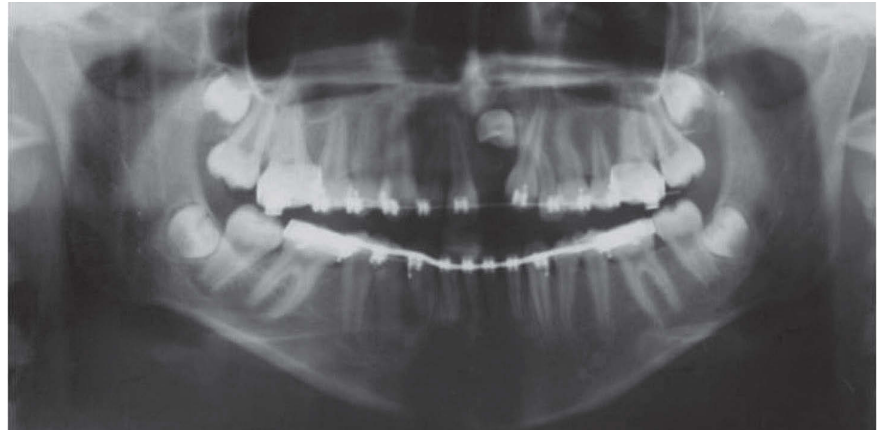


Figure 4 - Panoramic radiograph revealing impaction of tooth #21, #22 and #23 with incomplete transposition.

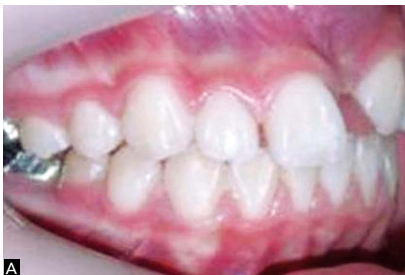


Figure 5 - Intraoral photographs with fixed appliance removed and new bands with triple tubes properly cemented. **A)** Right lateral view. **B)** Frontal view. **C)** Left lateral view.



Figure 6 - Intraoral photograph showing fixed appliance: **A)** Right lateral view. **B)** Frontal view and **C)** Left lateral view with TMA semiarch for #23 intrusion.



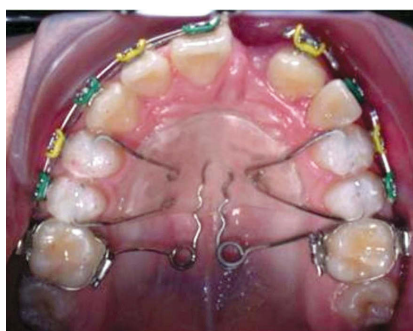


Figure 7 - Hilgers appliance properly installed.

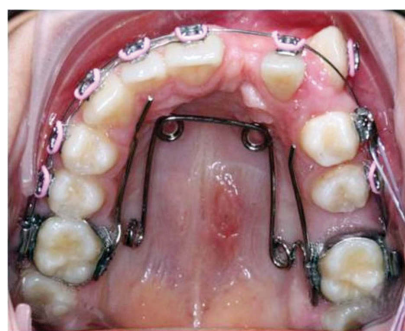


Figure 8 - Quad-helix appliance installed to maintain distalization of #26.



Figure 9 - Distalization of tooth #23 with closed NiTi spring and mesialization of #22 with open NiTi spring.



Figure 10 - Upper arch alignment after transposition.

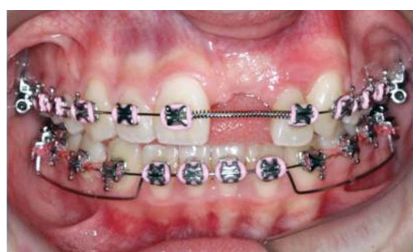


Figure 11 - Upper arch with open steel spring used to keep the space left for traction of retained tooth #21.



Figure 12 - Traction of tooth #21 carried out with 0.014 NiTi wire superimposed to 0.016 x 0.016-in square stainless steel archwire with open spring between #11 and #22.

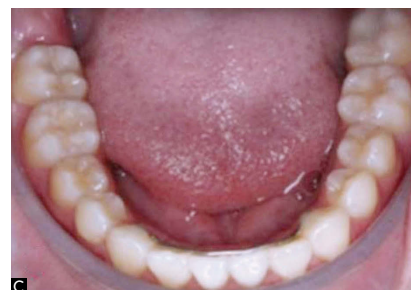
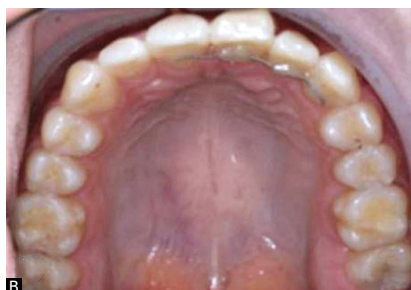
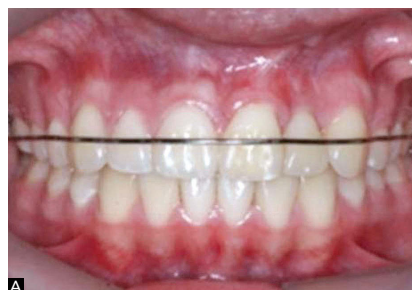


Figure 13 - Final intraoral photographs: **A)** Frontal view with Hawley retainer. **B)** Occlusal view of upper arch with fixed retainer from tooth #11 to 23. **C)** Lower occlusal view with fixed lingual arch.



Figure 14 - Final intraoral photographs: A) Right lateral view. B) Frontal view. C) Left lateral view.

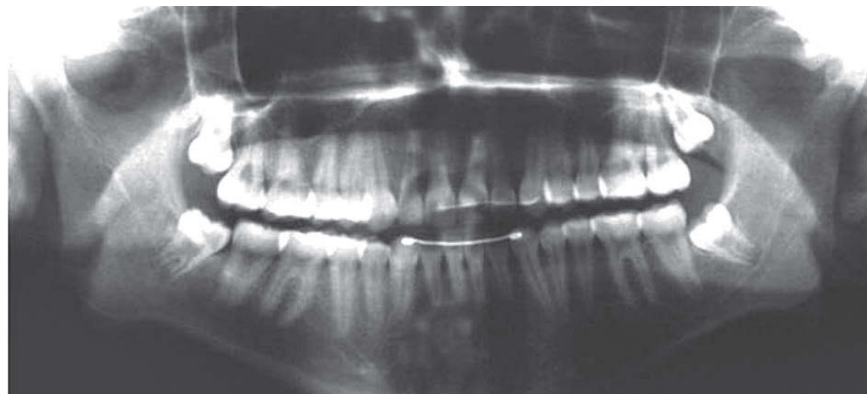


Figure 15 - Final panoramic radiograph.

The basal bone most often affected is the maxilla, with higher incidence of unilateral transposition, which, in this case, the left side prevailed.¹²⁻²⁴ The teeth mostly affected by transposition are canine and first premolar¹² as well as canine and lateral incisor.²⁵ The case reported herein presented incomplete transposition between the canine and lateral incisor on the left side, associated with impacted upper left central incisor.

In the presence of an impacted tooth, a frequent complication of traction is the possibility of the tooth not moving due to ankylosis.²⁶ Moving an impacted tooth involves risks of devitalization, discoloration, external root resorption, injury to adjacent teeth, alveolar bone loss, gingival recession, increase in clinical crown length and tooth sensitivity, which can lead to esthetic problems or tooth loss.²⁷ In the reported case, alveolar bone resorption existed prior to treatment. Gingival recession and increased clinical crown were also observed.

Traction and conservation of retained anterior teeth, both esthetically and functionally, it is the alternative therapy with the most favorable outcomes.²⁸ There is a great demand for satisfactory esthetic outcomes in the anterior region, and no prosthetic material is superior to the tooth itself. Occlusal problems also decrease, since

there is no tooth loss and the arch remains symmetrical and complete.⁸ Another important aspect is that the volume of alveolar bone loss resulting from extraction of the incisor is avoided, a frequent situation which is difficult to be solved.²⁸ Thus, in the case reported herein, traction of tooth #21 was the treatment of choice, yielding satisfactory esthetic and functional results. The surgical technique used was the closed technique, in which the tooth is tractioned inside the mucosa and alveolar bone. This technique presents stability, periodontal anatomy and final esthetic results that are more favorable than apical reposition of the flap with immediate exposure of the crown after surgery.²⁸

The technique as well as the orthodontic appliances used in the traction of impacted teeth or in transposition correction will depend on a correct diagnosis and treatment plan.^{1,3,7,15} When adjacent teeth require individualized and controlled movements, fixed appliances are indicated⁸. The mechanics of choice must be carefully planned.^{3,7,13,15} In this case, the segmented arch technique was performed with the use of devices such as cantilever and loop in rectangular wires, which allowed the professional to work with a control system of strength with regard to movement of the central incisor, lateral incisor and canine as well as anchorage

units performed individually.^{3,7,10} However, the treatment involves risks, requiring extremely controlled mechanics, care and accurate application to overcome the possibility of failure.

Maintaining the central incisor, lateral incisor and canine in their usual position was essential to achieve balanced occlusion, periodontal health, facial harmony and for establishing patient's esthetics. Canine guidance was another very positive aspect of the case. As a consequence, protrusive and lateral movements were properly maintained, constituting an element of protection of the stomatognathic system, as well as the molar ratio of Class I Angle and correct overjet and overbite, thus allowing occlusal stability and proper dental esthetics.^{3,7}

In view of a case involving tooth transposition between canine and lateral incisor associated with impaction of the

central incisor, the orthodontist must be committed to positioning these teeth correctly, leveling and aligning them in the dental arch within the biological principles that guide the integrity of adjacent tissue structures, thus resulting in a successful treatment.^{8,10,12} The technique of traction and tooth transposition proved to be highly satisfactory, restoring patient's esthetics and harmonious occlusal relationships.

CONCLUSION

In the reported case, the choice of transposition and orthodontic traction carried out by means of the segmented arch technique performed with devices such as cantilever and loops in rectangular wires, despite being a more difficult alternative, proved to be effective from an esthetic and functional standpoint.

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Compensatory orthodontic treatment of skeletal Class III malocclusion with anterior crossbite

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Introduction: This case report describes the orthodontic treatment of an adult patient with skeletal Class III malocclusion and anterior crossbite. A short cranial base led to difficulties in establishing a cephalometric diagnosis. The patient's main complaint comprised esthetics of his smile and difficulties in mastication.

Methods: The patient did not have the maxillary first premolars and refused orthognathic surgery. Therefore, the treatment chosen was orthodontic camouflage and extraction of mandibular first premolars. For maxillary retraction, the vertical dimension was temporarily increased to avoid obstacles to orthodontic movement.

Results: At the end of the treatment, ideal overjet and overbite were achieved.

Conclusion: Examination eight years after orthodontic treatment revealed adequate clinical stability. This case report was submitted to the Brazilian Board of Orthodontics and Facial Orthopedics (BBO) as part of the requirements to become a BBO diplomate.

Keywords: Crossbite. Tooth extraction. Corrective orthodontics.

» The patient displayed in this article previously approved the use of her facial and intraoral photographs.

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INTRODUCTION

A 22-year and 10-month-old male patient arrived for his initial examination in good general health, complaining about his smile, particularly an anterior crossbite and maxillary diastemas, as well as difficulties associated with mastication. His dental history included the extraction of maxillary first premolars at the age of 12, carried out by a clinical dentist due to lack of adequate space for eruption of maxillary canines.

DIAGNOSIS

Facial examination revealed balanced characteristics: mesofacial pattern, symmetric features and adequate lip seal. However, a sagittal maxillomandibular deficiency was also noted. The patient had narrow nostrils, slightly ptotic nasal tip, paranasal deficiency, marked grooves at rest and when smiling, a short mentocervical line and an obtuse mentocervical angle, which confirmed the diagnosis. There was also a discrete predominance of maxillary deficiency (Fig 1).



Figure 1 - Initial facial and intraoral photographs.

The examination of temporomandibular joints revealed bilateral clicking at mandibular opening and closing, maximal mouth opening of 43 mm and an irregular path, but no pain.

Intraoral clinical examination revealed adequate oral hygiene. Malocclusion was classified as Angle Class I with anterior crossbite, absence of maxillary first

premolars, canines in full Class III relationship, anterior mandibular crowding, rotated maxillary central incisors and anterior diastemas (Figs 1 and 2). There were no differences between usual maximal intercuspation and centric relation. Radiographs showed that the patient had good dental and periodontal health and no endodontic problem or bone loss (Figs 3 and 4).

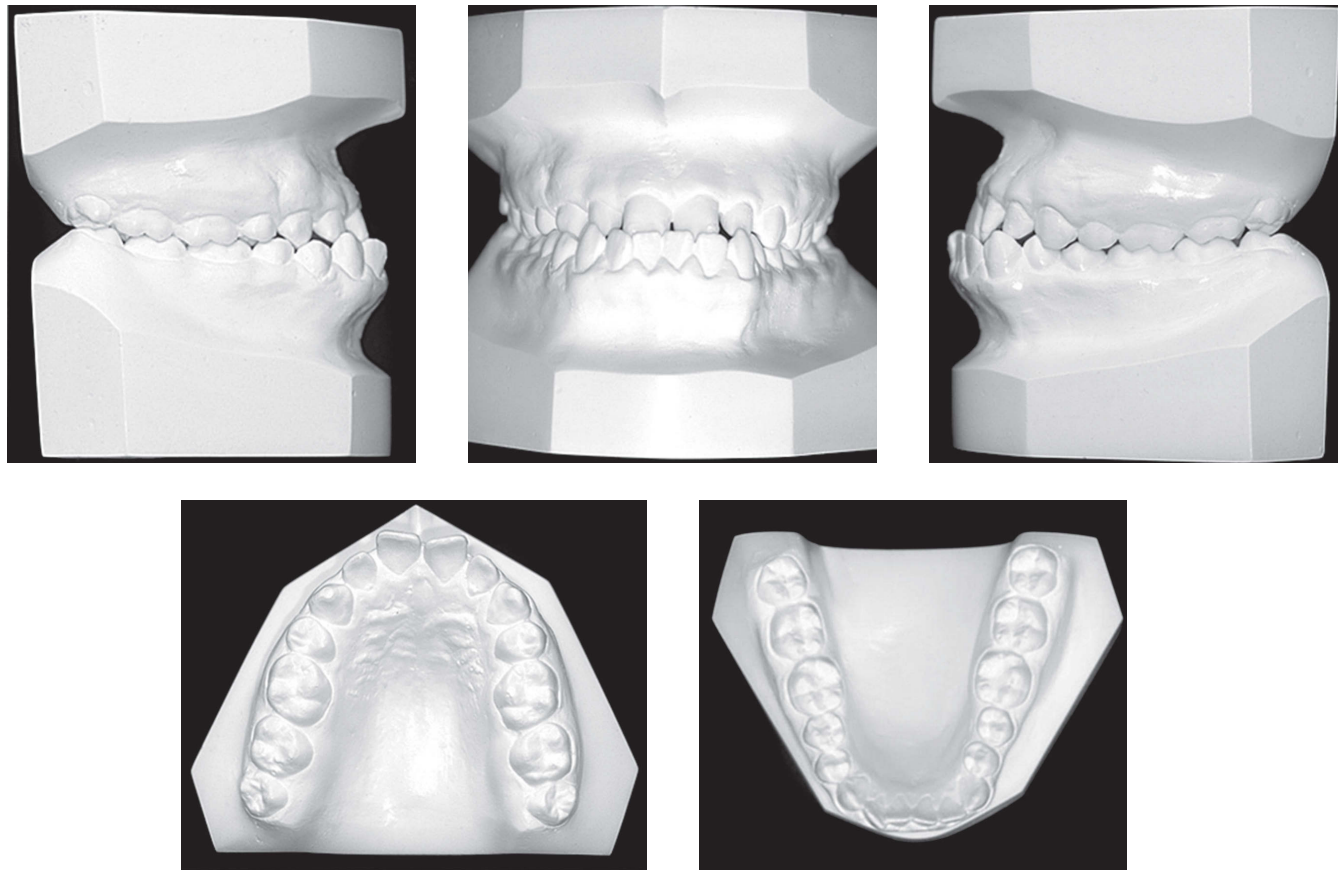


Figure 2 - Initial casts.



Figure 3 - Initial panoramic radiograph.

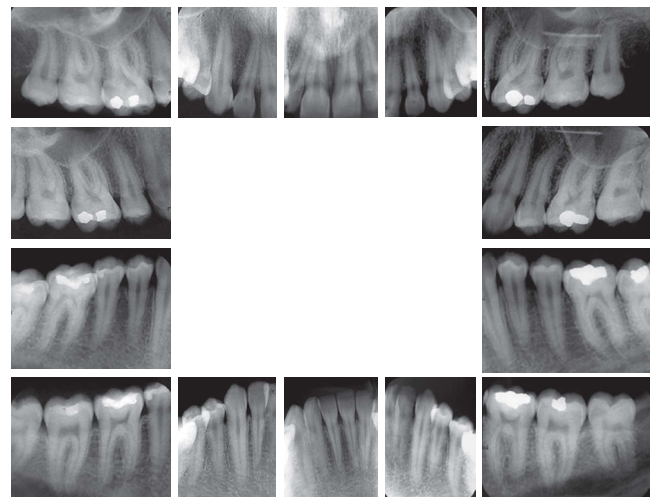


Figure 4 - Initial periapical radiographs.

Cephalometry revealed that the maxillomandibular relationship was apparently normal ($ANB = 2^\circ$) and that a few angles were slightly greater than normal ($Conv. = 5.5^\circ$; $SNA = 86^\circ$; $SNB = 84^\circ$) (Fig 5). However, the ANB angle is known to be markedly affected by geometrical factors.¹ When the cranial base is short, maxillomandibular discrepancies cannot be evaluated on the sagittal plane using the ANB angle (Fig 6). Other cephalometric parameters ($Wits = -8$ mm; $S-N = 71.5$ mm) and particularly facial analysis should be used to elucidate this confounding factor.^{2,3}

When evaluated by cephalometry and having the cranial base as reference, maxillary and mandibular incisors showed buccal inclination and marked protrusion ($1-NA = 25^\circ$, $1-NA = 7$ mm) in mandibular teeth ($1-NB = 34^\circ$, $1-NB = 11$ mm). In contrast, the inclination of mandibular incisors in relation to the mandibular plane was good and met the Brazilian standards ($IMPA = 94^\circ$).²

TREATMENT PLAN

The first treatment plan presented to the patient was the orthodontic combined with orthognathic surgery,

which the patient promptly refused. For this reason, an alternative plan was suggested. It included orthodontic camouflage with orthodontic appliances in both arches and extraction of mandibular first premolars. The patient had undergone extraction of maxillary first premolars and, therefore, our aim was to achieve normal molar and canine occlusion. Mandibular extractions followed by retraction of anterior teeth should be supported by adequate anchorage control.

The dentist and the patient agreed on the following objectives for the treatment selected: preservation of maxillary and mandibular bones position; alignment and reduction in maxillary diastemas; alignment of mandibular teeth; normal occlusion, correction of negative overjet and functional occlusion; esthetic improvement after lower lip retraction; and achievement of a pleasant smile.

Treatment plan was divided into the following phases: modified Nance lingual arch (away from mandibular incisors); fixed orthodontic appliances in both arches using the straight-wire system and 0.022x0.028-in slots; extraction of mandibular first premolars; tooth leveling and alignment with

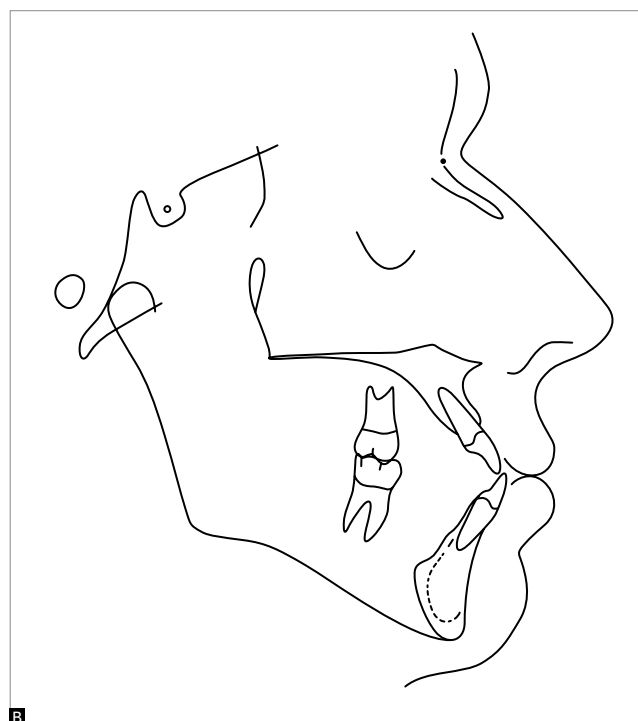
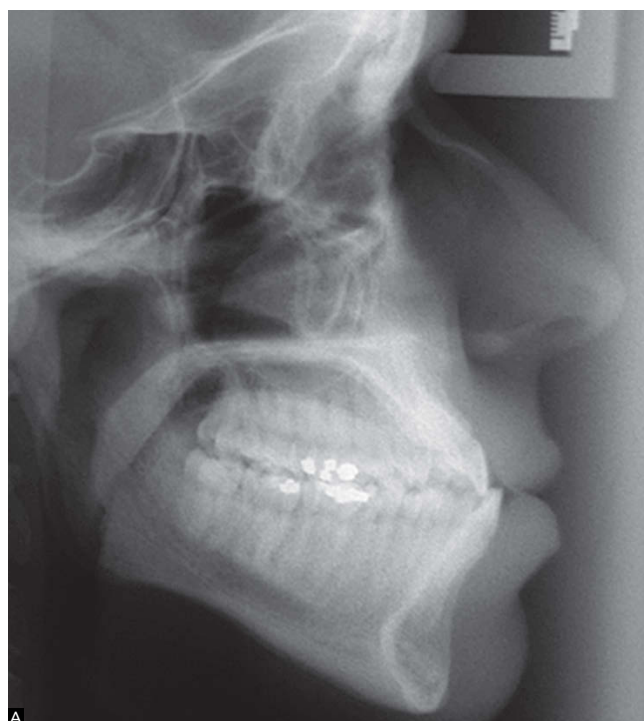


Figure 5 - A) Initial cephalometric profile radiograph and B) cephalometric tracing.

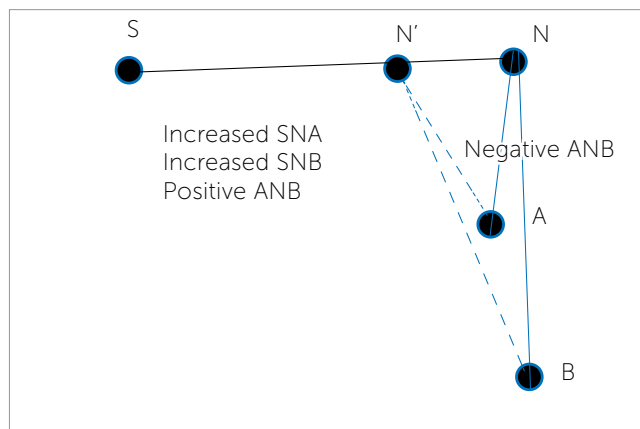


Figure 6 - Diagram illustrating Class III skeletal relationship with short (N') and normal (N) anterior cranial bases.

0.012-in, 0.014-in and 0.016-in nickel-titanium wires and 0.018-in, 0.020-in and 0.017x0.025-in stainless steel wires; retraction of mandibular anterior teeth using sliding mechanics and 0.019x0.025-in stainless steel wire; removal of lingual arch; orthodontic treatment finishing; retention.

TREATMENT PROGRESSION

Treatment progression was in accordance with the plan. Mandibular second molars were included in initial

leveling to aggregate an anchorage unit for the retraction of incisors. Maxillary second molars were bonded and included in leveling during orthodontic finishing.

The vertical dimension had to be temporarily increased with glass-ionomer cement built-up on posterior teeth. This procedure was used for retraction of mandibular anterior teeth because anterior crossbite and marked overjet were obstacles to movement (Figs 7A, B and C). Spaces were closed by means of sliding mechanics (0.019x0.025-in wire) and hooks were soldered between canines and lateral incisors. Class III intermaxillary elastics (1/4-in, medium force) were used to control anchorage together with the lingual arch which was removed after retraction of anterior teeth and closing of extraction spaces. No skeletal anchorage was used. Treatment was completed with 0.018-in archwires, elastic chains in both arches to retain interproximal contacts, and Class II intermaxillary elastics (5/6-in, medium force) to retain the movement achieved (Figs 7D, E and F). After orthodontic completion, intercuspation was good, and canine and molar occlusion relationships, as well as overjet, were normal (Fig 8, 9). Maxillary (2 x 2) and mandibular (4 x 4) V-looped braided bonded lingual archwires were placed for retention.

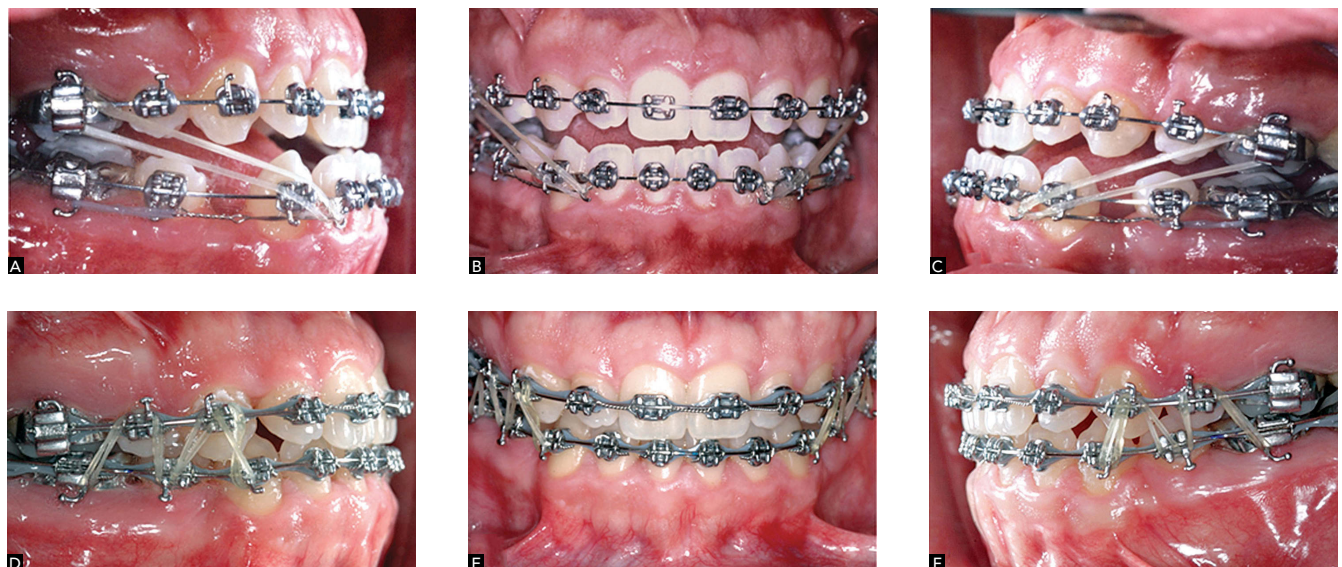


Figure 7 - Increased vertical dimension during retraction of mandibular anterior teeth (A, B, C) and treatment completion phase (D, E, F).



Figure 8 - Final facial and intraoral photographs.

RESULTS

The final radiograph showed that root parallelism was good after space closure and that root size was preserved (Figs 10 and 11).

In the maxillary arch, diastemas were reduced, molars were slightly extruded, intercanine distance (35.5 mm) was preserved and intermolar distance was shortened

(from 43.5 mm to 42.0 mm). A marked cephalometric effect was found in the mandibular arch with anterior retraction, intrusion and mesial movement of mandibular molars (Fig 12 and Table 1). However, intercanine (21.5 mm) and intermolar (33.0 mm) distances did not change.

There were no significant changes in the position of the maxilla or the mandible (Fig 13). Facial esthet-

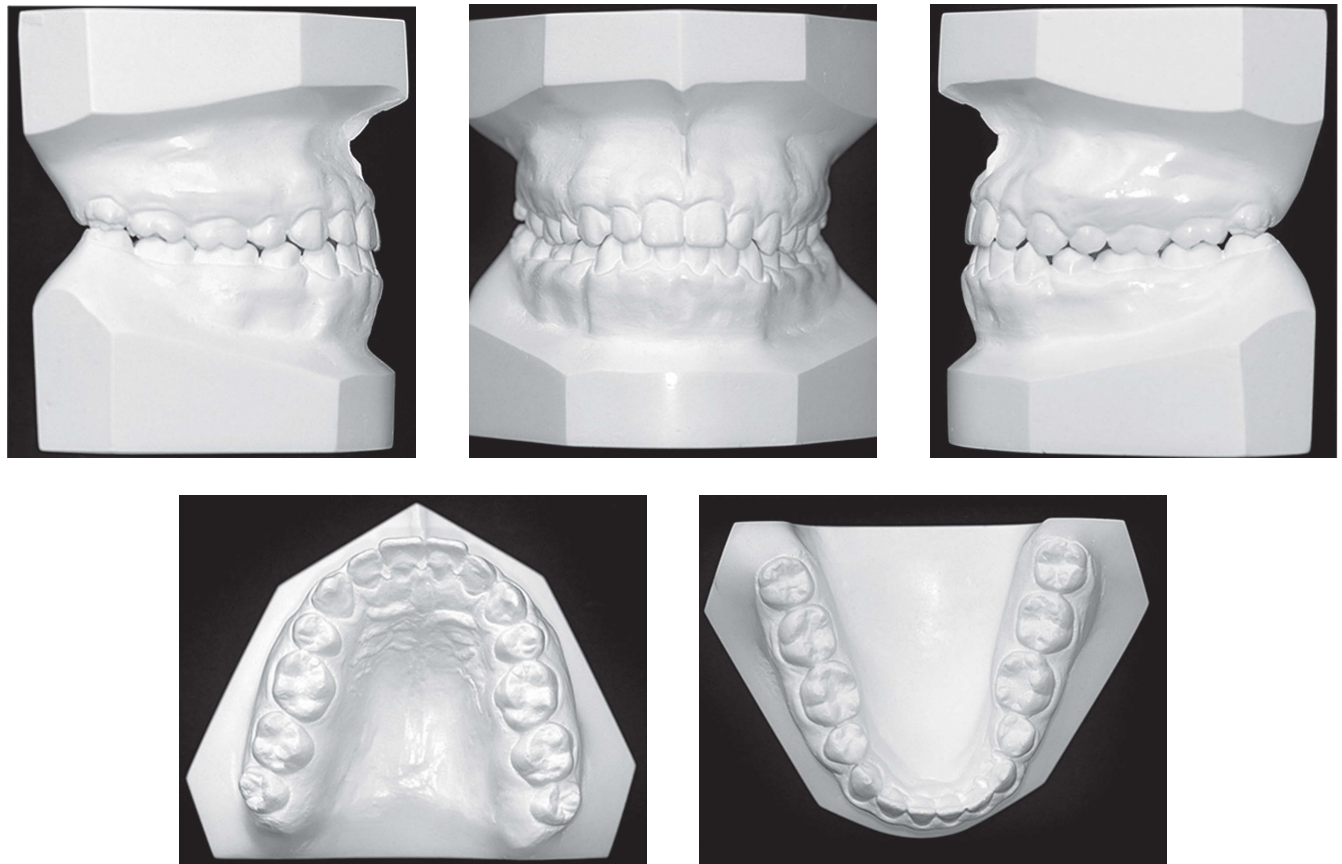


Figure 9 - Final casts.



Figure 10 - Final panoramic radiograph.

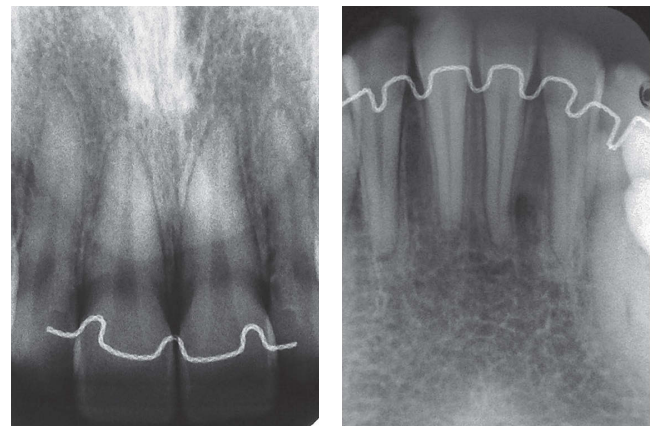


Figure 11 - Final periapical radiographs of maxillary and mandibular incisors.

ics improved due to less marked lower lip protrusion, confirmed by reduction of 2.5 mm in the cephalometric variable that describes the lower lip (S line) (Fig 14 and Table 1).

The relationship between the maxilla and the mandible showed good intercuspatation and coordination, although sagittal skeletal discrepancy was camouflaged

by dental compensation. Overjet and overbite were fully corrected, and the criteria for ideal functional occlusion were met. The positive results, confirmed by clinical stability eight years after treatment completion, were favored by the lack of remaining facial growth, the use of fixed retention and patient's satisfactory occlusal relationship (Fig 15).



Figure 12 - A) Final cephalometric profile radiograph and B) cephalometric tracing.

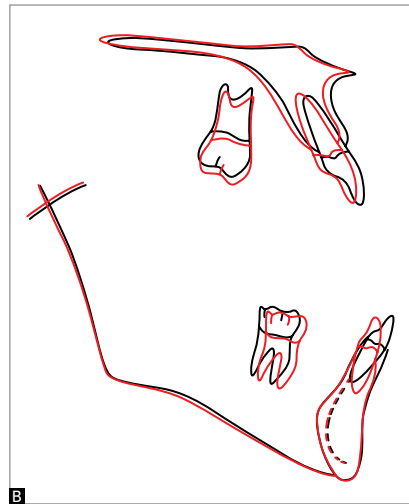
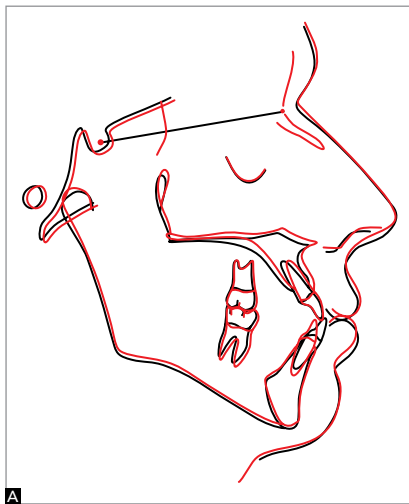


Figure 13 - A) Total and B) partial superimpositions of initial (black) and final (red) cephalometric tracings.

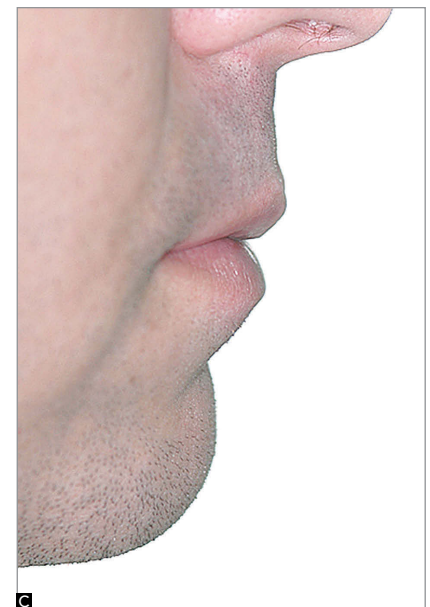
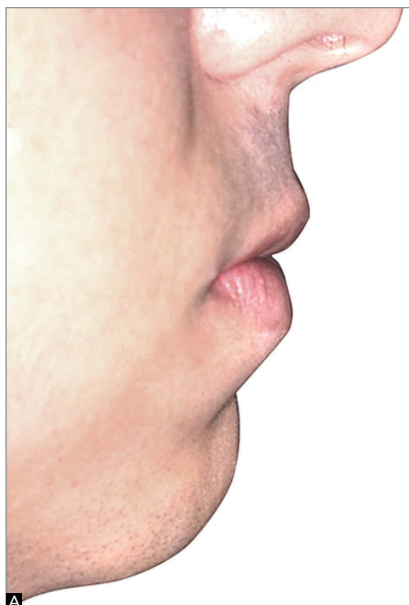


Figure 14 - Comparison of facial profile close-up: A) initial, B) final and C) control eight years later.



Figure 15 - Facial and intraoral control photographs eight years after treatment completion.

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

	Measures		Normal	A	B	A/B diff.
Skeletal pattern	SNA	(Steiner)	82°	86°	85°	1°
	SNB	(Steiner)	80°	84°	83°	1°
	ANB	(Steiner)	2°	2°	2.5°	-0.5°
	Facial angle	(Downs)	0°	5.5°	6.5°	-1.0°
	Y axis	(Downs)	59°	57°	57°	0°
	Facial angle	(Downs)	87°	93°	92°	1°
	SN-GoGn	(Steiner)	32°	34°	34°	0°
	FMA	(Tweed)	25°	26°	23°	3°
Dental pattern	IMPA	(Tweed)	90°	94°	78°	16°
	1.NA	(Steiner)	22°	26°	25°	1°
	1-NA	(Steiner)	4 mm	7 mm	6 mm	1 mm
	1.NB	(Steiner)	25°	34°	17°	17°
	1-NB	(Steiner)	4 mm	11 mm	4 mm	7 mm
	1.1 – Interincisal angle	(Downs)	130°	115°	135°	-20°
	1-APo	(Ricketts)	1 mm	10 mm	5 mm	5 mm
Profile	Upper lip – S line	(Steiner)	0 mm	0 mm	0 mm	0 mm
	Lower lip – S line	(Steiner)	0 mm	3 mm	0.5 mm	2.5 mm

FINAL CONSIDERATIONS

Cranial base abnormalities strongly affect the interpretation of cephalometric variables in this region, particularly SNA, SNB, ANB and convexity angle. Other cephalometric parameters, correction factors and, above all, facial analysis findings contributed to making the diagnosis and developing a treatment plan. In adults, Class III skeletal patterns may often be treated with

either orthodontic camouflage or orthognathic surgery.^{4,5} In the case reported here, the treatment chosen was orthodontic camouflage with extraction of mandibular first premolars. Treatment results were satisfactory, and the occlusal objectives were achieved. The final harmonious smile pleased the patient and improved his self-esteem and quality of life.

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Life-quality of orthognathic surgery patients: The search for an integral diagnosis

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The decision on whether starting an orthosurgical treatment depends on the negative esthetic, functional and social impact the dentofacial deformity has on the quality of life of each patient. The objective of this article is to demonstrate the importance of assessing the quality of life of these individuals by means of applying specific questionnaires before treatment onset in order to increase the success rate of orthosurgical treatment. These questionnaires assess not only the esthetic factor, but also the functional conditions that may be affected as well as the psychological issues related to self-esteem and sociability, all of which must be assessed in order to enable the development of an individual treatment plan that meets patient's expectations. Thus, a more predictable level of satisfaction can be achieved at treatment completion, not only from a normative standpoint stated by professionals, but also from a subjective standpoint stated by patients. Although not enough comparable data is available in the literature for us to assess the extent of improvements produced by orthosurgical treatment, a few recent reports conducted by different universities around the world reveal a good response from the majority of patients after surgery, demonstrating great satisfaction with regard to esthetic, functional and psychosocial factors. Therefore, it is reasonable to conclude that the current objective of orthodontic treatment associated with orthognathic surgery consists not only in treating the esthetic functional components of dentofacial deformities, but also in considering patients' psychological factor.

Keywords: Quality of life. Orthodontics. Orthognathic surgery.

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

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INTRODUCTION

Facial esthetics strongly influences personal and professional relations, especially in school and professional environments, from childhood to adulthood.^{1,2,3} Patients with severe malocclusions are dissatisfied with their physical appearance, particularly with their face.⁴ In cases of dentofacial deformities, in which patients wish to significantly change their face and solve their functional problems, orthosurgical treatment is the most suitable option.

Although the vast majority of published articles only highlight the surgical techniques available, assessing the effects of dentofacial deformities and orthosurgical treatment on the psyche of each patient is essential. Additionally, it is highly necessary that psychological and functional issues, social interaction trouble, low self-esteem and other negative impact that hinder patient's quality of life be identified.^{1,5,6}

The concept of "quality of life" was defined in 1993 by the World Health Organization as the perception of people with regard to their situation in life, within the cultural context and values with which they live, in relation to their objectives, expectations, patterns and concerns.⁷ Quality of life is essentially a subjective concept that cannot be judged by others.

According to the current paradigm of evidence-based Dentistry, all treatment procedures must be based on the systematic assessment of clinically relevant scientific evidence available which include patients' current condition, medical/dental history, treatment needs and preferences. Although the demand for orthosurgical treatment is strongly related with patients' chief complaint about their appearance, as well as with psychological and social interaction issues, assessments on the need for treatment give little emphasis on patients' perception and on how much treatment can improve their oral health-related quality of life.⁸

The ideal would be to implement objective clinical indexes as well as subjective indexes assessing the impact of dentofacial deformities on the daily routine of affected individuals. The results would reflect patients' demand and guide the priorities of public healthcare systems. Private practice allows orthodontists and dental surgeons to have a better understanding of patients' chief complaints and expectations with regard to treatment outcomes, allowing professionals to develop more personal treatment plans, with higher levels of foreseeability regarding patients' satisfaction at treatment completion.⁹

Motivations of patients who seek orthosurgical treatment

Over the years, studies have demonstrated that most patients with dentofacial deformities seek treatment in order to have their facial and dental esthetics improved.¹⁰ Additionally, some studies report that the main motivation comprises improvements in masticatory function rather than changes in appearance.¹¹ Patients also seek treatment with the expectation of gaining psychosocial benefits, including improvements in interpersonal relationships and psychological well-being, by improving their self-esteem.¹²

Some patients may have unreal expectations with specific objectives such as professional growth or romantic relationships. These cases are often related with previous frustrating experiences which the individual relates to the presence of his dentofacial deformities. These patients overestimate the influence this treatment has over their lives, which must be identified during the first interview conducted by both orthodontist and dental surgeon in order to prevent a possible misunderstanding between professionals and patients.

In spite of that, the most common situation identified in epidemiologic research as well as in orthodontic clinics is that patients expect to have improvements in their psychological well-being and their interpersonal relationships without directing their expectations towards unreal situations.

Available scientific literature investigating the theme agrees that patients believe that their lives will improve after orthodontic treatment.^{10,12}

Therefore, patients' subjective expectations, which considerably differ from those of orthodontists as well as from oral and maxillofacial surgeons, must be investigated before any intervention is carried out.^{1,5,8,12-18}

How to evaluate oral health-related quality of life?

Quality of life instruments can be addressed by direct or telephone interviews, self-filling questionnaires or, should the individual not be able to answer the questions himself, questionnaires filled in by other people.¹⁹ The most widely used method is the questionnaire filled in by the patient himself, given that this method reduces the chances of interference. Each questionnaire focuses on a different aspect

of quality of life evaluation: General health, oral health or specific health according to the condition under study (for instance, orthosurgical treatment).

The Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36) is a general quality of life instrument that assesses the impact of a problem, treatment or intervention over patients' general health perception. It comprises psychiatric questions of more widespread and less specific perception, and is mainly used by Medical Sciences to compare different populations, although its use is limited in Dentistry. Its 36 items assess 8 domains divided into two groups: Physical (functional capacity, physical aspects, pain and general health status) and mental (mental health, vitality, as well as psychosocial and emotional aspects). Its scoring varies from 0 (no negative impact on quality of life) to 100 (the worst quality of life possible).¹⁹

Among the questionnaires used to assess the impacts on oral health-related quality of life, the most widely used is the Oral Health Impact Profile (OHIP) developed in Australia by Slade et al,²⁰ and which assess the individual's perception regarding discomfort and dysfunction caused by oral conditions. Its 49 items are divided into seven dimensions: Functional limitation, physical pain, psychological discomfort, physical incapacity, psychological incapacity, social incapacity and difficulty doing usual jobs. Its short version, known as OHIP-14, was published in 1997²¹ and comprises fourteen questions that assess the same seven dimensions (Fig 1). The interviewee must score points to each question according to the frequency with which he is affected: 0 = never; 1 = hardly ever; 2 = occasionally; 3 = fairly often and 4 = very often. The sum of points for the 14 questions gives the final OHIP-14 score which may vary between 0 and 56, in which 0 means absence of negative impact and 56 means the worst negative impact on oral health-related quality of life. The Brazilian version of the OHIP-14 proved to have psychometric properties that are similar to the original questionnaire.²²

The Orthognathic Quality of Life Questionnaire (OQLQ) was developed and validated by Cunningham et al^{23,24} whose objective was to assess the impact of dentofacial deformities and the benefits of orthosurgical treatment on patients' quality of life (Fig 2). This questionnaire has been widely used in researches^{14,16,18} and comprises 22 questions divided into four domains: Facial esthetics, oral function, awareness of facial esthetics and social aspects. Patients can choose the option "it does not

bother me" (0 points) or, should they be affected by any of the issues, they use a 4-point scale of which answers vary from "it bothers me a little" (1 point) to "it bothers me a lot" (4 points). OQLQ total score can vary from 0 to 88. A lower score suggests improvements in quality of life, whereas a higher score suggests that the quality of life has become worse. The OQLQ has already been translated into Brazilian Portuguese^{25,26} with its psychometric properties being kept. Thus, the B-OQLQ is an instrument that must be used when assessing Brazilian orthodontic-surgical patients.

OHIP-14					
In the last six months	Never	Hardly ever	Occasionally	Fairly often	Very often
1) Have you had trouble pronouncing any words because of problems with your teeth, mouth or dentures?					
2) Have you felt that your sense of taste has worsened because of problems with your teeth, mouth or dentures?					
3) Have you had painful aching in your mouth?					
4) Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth or dentures?					
5) Have you been worried by dental problems?					
6) Have you felt tense because of problems with your teeth, mouth or dentures?					
7) Has your diet been unsatisfactory because of problems with your teeth, mouth or dentures?					
8) Have you had to interrupt meals because of problems with your teeth, mouth or dentures?					
9) Have you found it difficult to relax because of problems with your teeth, mouth or dentures?					
10) Have you been a bit embarrassed because of problems with your teeth, mouth or dentures?					
11) Have you been a bit irritable with other people because of problems with your teeth, mouth or dentures?					
12) Have you had difficulty doing your usual jobs because of problems with your teeth, mouth or dentures?					
13) Have you felt that life in general was less satisfying because of problems with your teeth, mouth or dentures?					
14) Have you been totally unable to function because of problems with your teeth, mouth or dentures?					

Figure 1 - Oral health impact profile questionnaire: Short version (OHIP-14).

OQLQ

Please read the following statements carefully. In order to find out how important **each of the statements** is to you, please circle **1, 2, 3, 4** or **N/A** where:

- 1** means it *bothers you a little*
4 means it *bothers you a lot*
2+3 lie *between these statements*
N/A means the statement does not apply to you or does not bother you at all

1	2	3	4
Bothers you a little			Bothers you a lot
1. I am self-conscious about the appearance of my teeth	1	2	3 4 N/A
2. I have problems biting	1	2	3 4 N/A
3. I have problems chewing	1	2	3 4 N/A
4. There are some foods I avoid eating because the way my teeth meet makes it difficult	1	2	3 4 N/A
5. I don't like eating in public places	1	2	3 4 N/A
6. I get pains in my face or jaw	1	2	3 4 N/A
7. I don't like seeing a side view of my face (profile)	1	2	3 4 N/A
8. I spend a lot of time studying my face in the mirror	1	2	3 4 N/A

9. I spend a lot of time studying my teeth in the mirror	1	2	3	4	N/A
10. I dislike having my photograph taken	1	2	3	4	N/A
11. I dislike being seen on video	1	2	3	4	N/A
12. I often stare at other people's teeth	1	2	3	4	N/A
13. I often stare at other people's faces	1	2	3	4	N/A
14. I am self-conscious about my facial appearance	1	2	3	4	N/A
15. I try to cover my mouth when I meet people for the first time	1	2	3	4	N/A
16. I worry about meeting people for the first time	1	2	3	4	N/A
17. I worry that people will make hurtful comments about my appearance	1	2	3	4	N/A
18. I lack confidence when I am out socially	1	2	3	4	N/A
19. I do not like smiling when I meet people	1	2	3	4	N/A
20. I sometimes get depressed about my appearance	1	2	3	4	N/A
21. I sometimes think that people are staring at me	1	2	3	4	N/A
22. Comments about my appearance really upset me, even when I know people are only joking	1	2	3	4	N/A

Figure 2 - Quality of life questionnaire for orthodontic-surgical patients (OQLQ).

How is the quality of life of patients with dentofacial deformities?

Combined orthodontic and orthognathic surgery therapy is the most appropriate treatment option for patients with facial deformities, given that it allows facial harmony to be established by surgical repositioning of jaw bones. Another treatment option includes orthodontic camouflage, however, this therapy only acts in dental positioning and inclination, improving intercuspation without significant changes in facial esthetics.

Improvements in facial esthetics have been considered the main motivating factor for patients seeking orthosurgical treatment.²⁷ Such desire is explained by the role esthetics plays in interpersonal and professional relationships,¹⁹ which suffer social and psychological implications when facial deformities are present.¹⁸ In other words, patients with

dentofacial deformities are subject to prejudgment that may hinder their social relations and influence their self-body image.¹²

Self-body image comprises two elements: The first is the individual's self-image seen in a mirror or in a photograph; while the second, and most important, is how the individual feels towards his features. Patients with a positive self-body image have higher chances of presenting more realistic expectations towards the outcomes of corrective procedures to which they will undergo in comparison to patients with a negative self-image.¹⁷ It is essential that clinicians clearly understand the expectations of patients who seek orthosurgical treatment, given that such therapy causes significant changes in individuals' body image. Should the dental surgeon and the orthodontist in charge be unaware of patients' expectations, or should any desires related to the therapy not be accomplished by the end of treatment, the outcomes

may end up being very frustrating, even if the objectives initially set by the professionals, by means of normative indexes, are achieved.^{12,17}

That is how the application of specific questionnaires aimed at assessing orthodontic-surgical patients' quality of life in clinical practice can contribute to diagnosis and treatment planning. These instruments assess not only esthetic aspects, but also functional conditions that may have been affected (for instance, mastication, speech and breathing) as well as psychological issues related to self-esteem and sociability.¹⁷

Impact of orthosurgical treatment on quality of life

Recent reports focusing on patients' satisfaction demonstrate good response after surgery, which has been confirmed by many authors.^{1-3,5,6,12,15,16,18} Nevertheless, lack of comparable data to assess the extent of improvements produced by orthosurgical treatment has been one of the main issues with regard to the available literature. This is mainly due to lack of consensus between the different indexes used to assess such changes.²⁷ Table 1 lists the clinical studies^{5,8,15,16,24,28-37} that assessed the effects of orthosurgical treatment on the quality of life of patients with dento-facial deformities (Table 1).

By applying the OHIP-14 questionnaire, Esperão et al⁸ observed that non-treated individuals seeking orthosurgical treatment suffered 6.5 times more negative impact on their quality of life than patients who had received orthosurgical treatment. In spite of presenting progressive worsening of occlusal aspects, patients who were undergoing orthodontic surgical preparation already presented improvements in quality of life, with three times more negative impact than operated patients. It is worth noting that women were the most affected in the pre-treatment phase.

These results were similar to those obtained by Rusanen et al⁴ who also detected by means of the OHIP-14 questionnaire that patients with facial deformities had more impact on their oral health-related quality of life than the general population, out of which female patients cared more about the opinion of other people.

Assessment of 93 Class II orthosurgical patients revealed significant improvements in quality of life during orthodontic preparation and post-surgical follow-up phases. Comparison of data obtained 2 years before

and 5 years after surgery revealed no significant changes, thus demonstrating stability of patients' quality of life. The psychosocial dimension was more positively affected than physical and functional aspects.³⁰

A prospective analysis of changes in the quality of life (assessed by OQLQ and OHIP-14) of 36 Class III malocclusion patients subjected to orthosurgical treatment⁷ revealed progressive reduction in OQLQ scoring six weeks after surgery, six months after surgery and at treatment completion.

However, OHIP-14 scoring revealed an important reduction only six weeks and six months after surgery. General quality of life, assessed by means of SF-36, also revealed significant improvements in mental health six months after surgery as well as in physical aspects six weeks after surgery. Thus, orthosurgical treatment was considered effective, producing significant psychosocial and functional improvements for patients.¹⁵

Lee et al⁵ also observed significant decrease in patients' general quality of life during the first six weeks after orthognathic surgery. Nevertheless, such decrease was transitory, and six months after surgery patients presented significant improvements.

A prospective analysis of 65 English patients who underwent orthosurgical treatment demonstrated significant gain in oral health-related quality of life, even during orthodontic preparation for surgery, despite the fact that the occlusal aspects progressively worsened. In the post-operative phase, oral health-related quality of life considerably improved. The most affected dimensions were: Social aspects, dentofacial esthetics and masticatory function.²⁴

In the United States, Flanary et al¹⁸ observed significant gain in patients' self-concept and self-image after orthosurgical treatment, with reduction in the incidence of personality disorders, psychosis and neurosis. Such gain remained even two years after surgery.

In Brazil, Costa et al³ corroborated these results by observing significant improvements in self-image and self-esteem of 15 patients who underwent orthognathic surgery. The majority of patients assessed sought treatment after being referred by other dentists or orthodontists. Family psychological support was of paramount importance for patients' recovery, and after surgery, patients observed major changes in their facial features as well as in their self-esteem. Most esthetic and functional problems reported by patients were corrected after surgery.

Authors	Type of study	Period of assessment	Instruments used	n	Objectives
Hatch et al ²⁸	Multicenter randomized clinical trial	Immediate pre and post-operative phase	Sickness Impact Profile, Oral Health Status Questionnaire, Symptom Checklist 90 Revised	117	Assess the effects of orthosurgical treatment on QoL and OHRQoL
Hatch et al ²⁹	Multicenter randomized clinical trial	Immediate pre and post-operative phase, six months and two years after surgery	Sickness Impact Profile, Oral Health Status Questionnaire, Symptom Checklist 90 Revised	117	Assess the effects of orthosurgical treatment on QoL and OHRQoL
Cunningham et al ²⁴	Longitudinal prospective study without control	Before treatment, before surgery and 8 weeks after treatment completion	OQLQ and SF-36	55	OQLQ validation
Motegi et al ³⁰	Multicenter randomized clinical trial	Immediate pre and post-operative phase, two and five years after surgery	Sickness Impact Profile, Oral Health Status Questionnaire, Symptom Checklist 90 Revised	93	Assess the maintenance of effects of orthosurgical treatment on QoL and OHRQoL
Nicodemo et al ³¹	Longitudinal prospective study without control	Before and after surgery	SF-36	29	Assess the effects of orthosurgical treatment on QoL
Lee et al ⁵	Longitudinal prospective study without control	Before and after surgery	SF-36, OHIP-14 and OQLQ	36	Understand the changes in OHRQoL of orthosurgical patients
Al-Ahmad et al ³²	Control case	Before treatment, before and after surgery	SF-36 and OQLQ	143	Assess the impact of orthosurgical treatment on three groups of patients in different phases
Choi et al ¹⁵	Longitudinal prospective study without control	Before treatment, before surgery, 6 weeks and 6 months after surgery and treatment	OHIP-14 and OQLQ	36	Understand the changes in OHRQoL and QoL of orthosurgical patients
Esperão et al ⁸	Cross-sectional study without control	Before treatment, before and after surgery	OHIP-14	117	Assess the impact of orthosurgical treatment on three groups of patients in different phases
Khadka et al ¹⁶	Longitudinal prospective study without control	Before and after surgery	SF-36 and OQLQ	152	Understand the changes in OHRQoL and QoL of orthosurgical patients
Murphy et al ³³	Longitudinal prospective study without control	Before and after surgery	OQLQ, Visual Analog Scale and Global Transition Scale	52	Understand the changes in OHRQoL of orthosurgical patients
Ballon et al ³⁴	Retrospective study without control	Before surgery, 8 weeks and one year after surgery	OHIP-14, OQLQ, Zung Depression Scale and Rosenberg Self-esteem Questionnaire	45	Understand the changes in OHRQoL, self-esteem and symptoms of depression in patients subjected to orthosurgical treatment
Rustemeyer and Gregersen ³⁵	Longitudinal prospective study without control	Before treatment and 12 months after surgery	OHIP-14	50	Understand the changes in OHRQoL of orthosurgical patients
Rustemeyer et al ³⁶	Longitudinal prospective study without control	Before and after surgery	OHIP-14	30	Assess the changes in OHRQoL before and after surgery, associating them with cephalometric changes in hard tissues
Kavin et al ³⁷	Longitudinal prospective study without control	Before surgery, 8 and 24 weeks after surgery	OHIP-14 and OQLQ	14	Understand the changes in OHRQoL of orthosurgical patients
Soh and Narayanan ²⁷	Systematic literature review	–	Patients' QoL and psychosocial analysis instruments	19 papers	Understand the scientific evidence available for orthosurgical treatment and QoL

Table 1 - Clinical studies assessing the effects of orthosurgical treatment on the quality of life of patients with dentofacial deformities.

Main conclusions

QoL and OHRQoL of patients subjected to orthosurgical treatment significantly improved

QoL and OHRQoL significantly improved after orthognathic surgery and the results remained after a two-year follow-up

OQLQ is a valid instrument that demonstrates improvements in OHRQoL of patients subjected to orthosurgical treatment

QoL and OHRQoL of patients subjected to orthosurgical treatment remained significantly improved two and five years after surgery (follow-up period)

Treatment significantly improved patient's QoL in physical and social aspects

Treatment significantly improved patients' OHRQoL in spite of temporary post-surgical worsening

The study suggests that orthosurgical treatment positively affects QoL and OHRQoL

Treatment significantly improved patients' OHRQoL in spite of temporary post-surgical worsening

The study suggests that orthosurgical treatment positively affects OHRQoL

Improvements in OHRQoL and QoL are significantly higher for patients with functional and esthetic complaints

Patients presented positive improvements in facial appearance, oral function and self-esteem

Orthosurgical treatment did not significantly influence any of the assessed items

Patients presented functional and psychological benefits after treatment

Reduction in lip-chin angle and nasion-pogonion distance as well as increase in facial convexity led to significant reduction/improvements in OHIP-14 scores

Treatment significantly improved patients' OHRQoL after 24 weeks in spite of temporary post-surgical worsening after 8 weeks

Patients' QoL and psychosocial aspects improved with orthosurgical treatment. A study by Motegi et al⁴³ is the best evidence available

Orofacial pain reports are usually associated with skeletal disharmony. Patients subjected to orthosurgical treatment reported improvements in masticatory function, speech and facial esthetics as well as reduction in articular and myofacial pain.³

Alves e Silva et al⁶ assessed the level of satisfaction of surgery performed in 15 orthosurgical Brazilian patients aged between 17 and 35 years old. Most patients (93%) claimed that surgery met their expectations, 33% had complaints with regard to the post-operative phase, especially in the first 24 hours after surgery (67%), whereas 60% complained about their eating habits in the first week after surgery (47%) and during maxillomandibular block with rubber bands (33%). As for social relations, 60% mentioned that they did not change, while 20% reported a slight increase and 20% reported a great increase.

Murphy et al³³ used the Global Transition Scale (GTS) to assess whether patients' conditions improved or worsened after surgery. Patients who underwent surgery reported to have improvements in the following aspects: Facial appearance (93%), masticatory function (64%), oral health welfare (60%) and speech (32%).

According to evidence available, it is clear that self-image continues to be positively affected during a long period of time after orthosurgical treatment.^{3,12} Nevertheless, improvements in self-image tend to decline when orthodontic finishing lasts for more than nine months. After this period, patients have already recovered from surgery and present functional as well as nutritional improvements. However, feeling that the treatment is incomplete causes some discomfort, which may influence the benefits obtained and negatively affect patients' quality of life. Despite being temporary, negative feelings originating from presurgical orthodontic preparation are significant issues with which patients must deal with. In addition, they are considered the worst disadvantage of this type of treatment, given that they cause patients' esthetic and functional conditions to worsen.^{8,12,13}

In conventional orthosurgical treatment, the pre-surgical orthodontic preparation phase is considered the worst aspect of treatment. It requires dental tipping decompensation and adaptation, in addition to significantly worsening patients' dentofacial aspects, thus producing negative esthetic and social impact and, as a consequence, worsening the social conditions

already observed before treatment onset, which may lead to an intense feelings of disadvantage.⁸

This preparation phase lasts for about 17 months, but may be carried out for a period not greater than two years.³⁸ It results in an ideal decompensation of dental tipping, space consolidation and coordination between the arches, thus allowing the best skeletal correction as well as the greatest possible stability.³⁹ Once an appropriate, precise and stable occlusion has been achieved in order not only to allow the orthognathic surgery to be carried out, but also perfectly align the arches, only minor adjustments are left for the postsurgical phase.³⁸

According to the literature, the postsurgical phase of conventional treatment lasts between seven and twelve weeks, and no changes regarding patients' age, sex and type of malocclusion were found to significantly change this duration.³⁸ For Kiyak,¹² the postsurgical treatment phase should not last for a period longer than nine months, since it could impair patients' psychological improvements.

According to Hernández-Alfaro et al,⁴⁰ the presurgical preparation phase may be even more harmful for patients with Class III malocclusion, given that mandibular prognathism results in dental decompensation that strongly emphasizes skeletal disharmony in these patients. In spite of that, patients with Class III malocclusion tend to prevail among Brazilian patients with skeletal malocclusion who seek orthodontic treatment.¹⁴

Some authors observed improvements during the preparation phase, however, their data have not been completely explained. For instance, by conducting a prospective analysis, Cunningham et al²⁴ concluded that orthosurgical treatment resulted in significant gains in OHRQoL of patients with dentofacial deformities. Patients' presurgical analysis revealed that a significant gain was obtained during presurgical orthodontic preparation in comparison with the results of the first examination, although the occlusal aspects progressively worsened. The second analysis was carried out six to eight weeks after orthodontic treatment finishing and, consequently, after orthognathic surgery was performed and the appliance was removed. It revealed significant improvements in oral health-related quality of life, which were greater than those found in previous analyses. The aspects that contributed the most for such important improvements in OHRQoL were: Social aspects, esthetics and masticatory function.

Despite being temporary, negative feelings originating from presurgical orthodontic preparation are significant issues with which patients must deal with. In addition, they are considered the worst disadvantage of this type of treatment, given that they cause patients' esthetic, functional and social conditions to become considerably worse than their initial malocclusion, the reason why they sought treatment.^{8,13,42}

Nevertheless, the impacts must cease to exist if the benefits obtained with surgery can be achieved within a shorter period of time by the "Anticipated Benefit" protocol.^{13,41} This protocol aims at foreseeing the magnitude of the skeletal changes that are necessary for treatment to be carried out, with orthognathic surgery being performed right after the orthodontic appliance has been placed. Orthognathic treatment (arch alignment and leveling) can only be performed after orthognathic surgery has been carried out. Theoretically, the tension and anxiety of going through orthodontic surgery preparation would cease to exist and the patient would experience the benefits of treatment more quickly, however, specific studies are warranted to confirm such hypothesis.

Feu¹⁴ compared the effects of two orthosurgical treatment protocols on the quality of life of 16 patients with Class III skeletal malocclusion during two years. The protocols were equally divided into two groups: Conventional treatment and anticipated benefit protocol. The main finding of this research was that the quality of life and esthetic self-perception of patients comprising the groups treated by the anticipated benefit protocol were significantly superior to those comprising the conventional treatment group during all assessment periods. Data were first assessed one month after treatment had been performed, during a two-year follow-up. These data revealed that, to date, treatment performed with the anticipated benefit protocol has a more positive psychosocial impact than conventional orthosurgical treatment. After two years, patients comprising the anticipated benefit protocol group were either undergoing the final stages of orthodontic finishing or had treatment already completed, and were then in retention. Conversely, none of the patients comprising the conventional group had been subjected to surgery and their quality of life had considerably become worse due to extended preparation time and worse

occlusal conditions. It is still unknown whether or not, after surgery, patients comprising the conventional treatment group will have quality of life scores and esthetic self-perception similar or better than those of patients comprising the anticipated benefit protocol group, given that their occlusal condition will be better after surgery due to presurgical orthosurgical treatment preparation.

According to evidence available, patients with dentofacial deformities present significant improvements in self-image after orthosurgical treatment, which continues to be positively affected during a long period of time after orthosurgical treatment.⁴² Nevertheless, improvements in self-image tend to significantly decline when orthodontic finishing lasts for more than nine months, in which case treatment seems to be incomplete. As reported by Kiyak et al,¹² in these cases, patients are no longer satisfied with treatment outcomes and present a reduction in their self-esteem and self-image, which theoretically is a result of losing psychological welfare. After this period of nine months, patients have already recovered from surgery and present functional as well as nutritional improvements, however, feeling that the treatment is incomplete causes discomfort, which may influence the benefits obtained.^{12,43} Additional studies are warranted to confirm whether or not these effects affect patients' OHRQoL.

Likewise, after six months, patients subjected to conventional orthosurgical treatment had mandibular movements as well as condylar displacement fully recovered.⁴⁴ These are important indicators of masticatory efficiency and adjustment of the temporomandibular joint which, in turn, may be related to the functional dimensions of the quality of life questionnaires, although no scientific evidence has yet proved such a fact.⁴⁵ Additional studies are warranted to further investigate the masticatory efficiency of patients treated with the anticipated benefit protocol. Therefore, assessing the functional dimensions of quality of life may provide important information on the adaptation of these patients during the postsurgical phase.

Longitudinal studies conducted with patients subjected to orthodontic treatment, regardless of the period of assessment, revealed that worse occlusal relationships were significantly related to a worse perception in oral health-related quality of life.^{46,47} In case of patients treated with the anticipated benefit protocol, even

after skeletal relationships and unpleasant esthetics had been corrected, patients' occlusion remained unbalanced and their masticatory function stability became worse.¹³ Therefore, additional studies are necessary to further investigate patients' perception in this new treatment condition, not comparable to any other type of treatment that has been previously investigated.

CASE REPORTS

Due to being an elective procedure, the decision of undergoing an orthosurgical treatment not only depends on patients' opinion, but also on their family's and on negative impact of the dentofacial deformity, whether esthetic, functional or social. For this reason, patients' expectations play an important role in predicting treatment final outcomes, given that their satisfaction is theoretically related to reduction or elimination of the factors that led them seek treatment. Thus, how can orthodontists or oral and maxillofacial surgeons be successful in performing an orthosurgical treatment that results in psychosocial gains for patients without knowing the impact caused by their dentofacial deformity?

Three cases of orthodontic-surgical patients treated at the Orthodontic Clinic of the State University of Rio de Janeiro, including normative and quality of life data, are reported herein. They demonstrate how joined analysis allows a more individualized treatment conduct to be carried out.

Case report 1

Caucasian, male, 22-year old patient sought treatment complaining about his dentofacial esthetics. As shown in his initial photographs (Fig 3), he presented Class III malocclusion, maxillary deficiency and mandibular excess.

His oral health-related quality of life was assessed by means of the OHIP-14 which scored 31 points (an index that varies from 0 to 56 points), and the B-OQLQ which scored 73 points (from 0 to 88 points), thus suggesting a considerably negative impact. For this reason, orthosurgical treatment was planned with the anticipated benefit protocol¹³ in order to quickly improve patient's facial esthetics.^{15,18}

An orthodontic appliance was placed and surgery associating maxillary advancement and mandibular setback was performed immediately after that.

After two years and seven months of treatment, the orthodontic appliance was removed. Satisfied with the final outcomes and the dental alignment obtained (Fig 4), the patient scored 4 points in the OQLQ and 4 points in the OHIP-14, which means he presented extremely significant improvements in oral health-related quality of life. In this case, the correct diagnosis of objective clinical data and patient's subjective perception led to successful orthosurgical treatment not only from a professional point of view, but also from a most important prospect, the patient's.

Case report 2

Non-Caucasian male, 26-year-old patient sought treatment complaining about his dental esthetics. As shown by his initial records (Fig 5), he presented Class II malocclusion, mild mandibular retrognathia and +6 mm overjet. He was considered a borderline case for which both treatment options were available: Orthognathic surgery and orthodontic camouflage. The patient was unsure about which treatment he should choose, but ended up opting for orthosurgical treatment with the expectation that it would yield better results.

His oral health-related quality of life was assessed. He scored 8 points in the B-OQLQ (from 0 to 88 points) and 11 points in the OHIP-14 (from 0 to 56 points), which suggested a minor negative impact on his oral health-related quality of life possibly due to presenting a slightly severe dentofacial deformity. A conventional orthosurgical treatment protocol was planned.

An orthodontic appliance was placed and after a preparation that lasted for 2 years and 5 months, mandibular advancement was carried out. The appliance was removed after a 6-month postsurgical orthodontic finishing phase (Fig 6). The patient reported no significant facial alterations and complained about postsurgical discomfort more often than the other patients did. After treatment, he scored 24 points in the OQLQ and 14 points in the OHIP-14, which meant his oral health-related quality of life became slightly worse.

In this case, the surgeon and the orthodontist should have noticed that the patient did not have a full perception of having a mild facial deformity and,

for this reason, he did not feel negative impact on his quality of life. Thus, the most appropriate treatment option would be an orthodontic camouflage with the aid of skeletal anchorage. Such protocol could have prevented the orthosurgical treatment from worsening the patient's quality of life.

Case report 3

Black male, 32-year-old patient sought treatment complaining about his dentofacial esthetics. He was eager to begin orthosurgical treatment. As shown in his initial records (Fig 7), he presented Class III malocclusion, with severe skeletal discrepancy, maxillary deficiency, mandibular excess and history of extraction of many teeth.

His oral health-related quality of life was assessed. He scored 59 points in the B-OQLQ and 26 points in the OHIP-14, which suggested a considerably negative impact on his oral health-related quality of life, corresponding to the severity of his dentofacial deformity. Due to the great need for orthodontic movement in his case, the conventional orthosurgical treatment protocol was chosen.

His B-OQLQ scores were assessed at different periods of orthodontic preparation, a phase the patient is still going through. After one month of orthodontic preparation, an initial reduction in the negative impact on patient's quality of life was observed, with a score of 43 points. Six months after preparation, the patient scored 51 points, suggesting that his condition became slightly worse. After one year of orthodontic preparation, he scored 63 points, an even more negative impact than his initial condition. The patient has been going through orthodontic preparation for two years now (Fig 8) and scores 77 points in OQLQ, thus demonstrating that the longer this treatment phase lasts, the more the patient's quality of life becomes worse due to postponing the benefits produced by esthetic and functional alterations.

These data suggest that there should be a preference for orthosurgical treatment protocols with a substantially reduced preparation phase, such as the anticipated benefit protocol, for patients to feel less negative impact on their quality of life.



Figure 3 - Initial facial and intraoral photographs.



Figure 4 - Final facial and intraoral photographs.

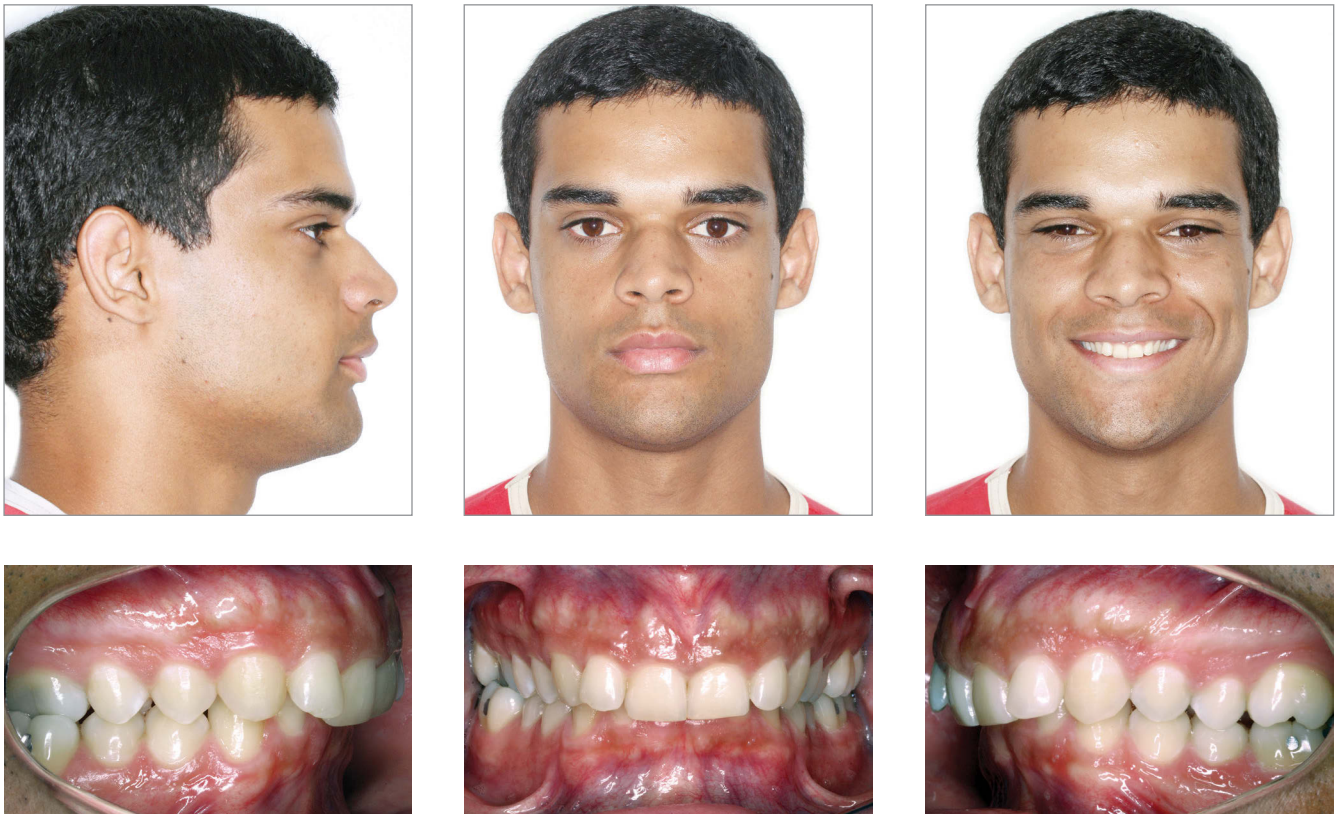


Figure 5 - Initial facial and intraoral photographs.

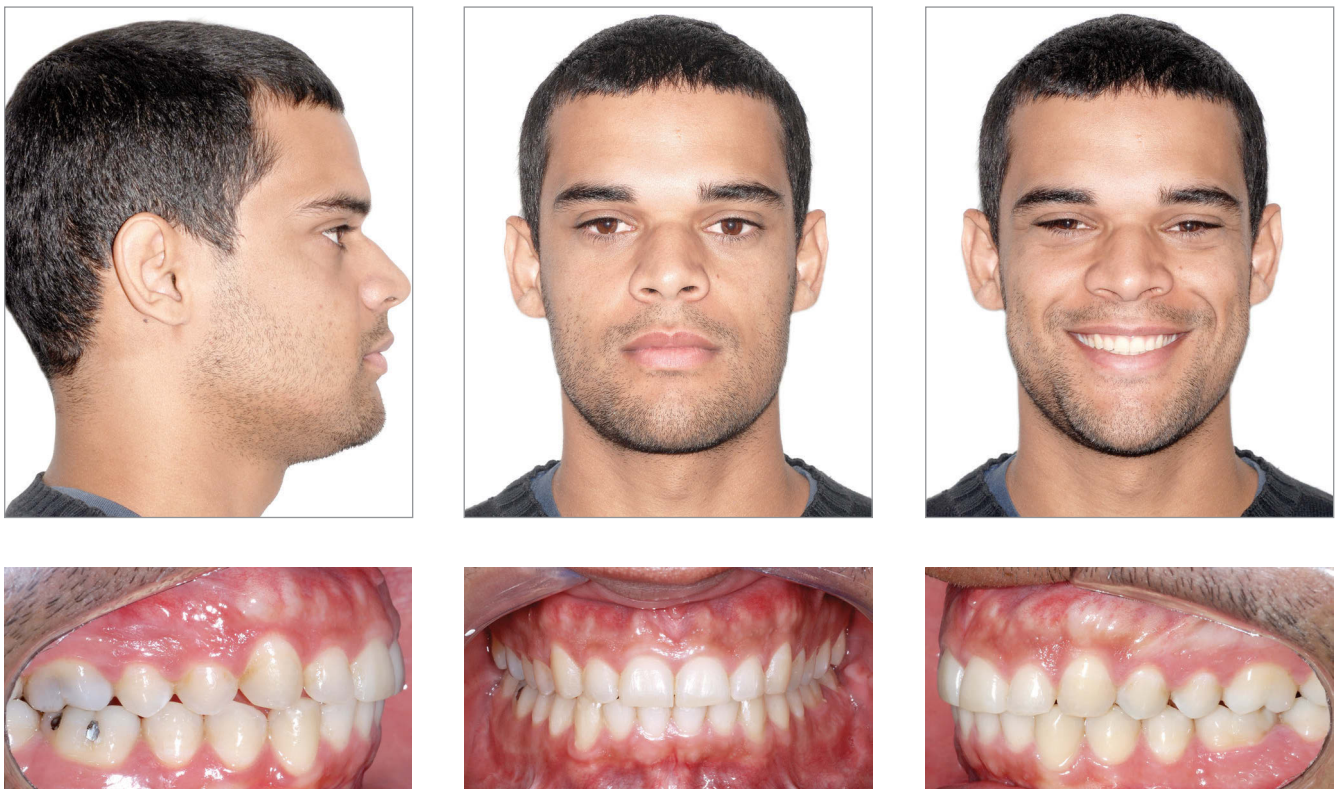


Figure 6 - Final facial and intraoral photographs.



Figure 7 - Initial facial and intraoral photographs.



Figure 8 - Patient's facial and intraoral photographs in the orthodontic preparation phase.

FINAL CONSIDERATIONS

The current objective of orthodontic treatment associated with orthognathic surgery consists not only in treating the esthetic functional components of dentofacial deformities, but also in considering patients' psychological factor. Both are parallelly influenced; but patients' motivations, perceptions and expectations play a significant role in obtaining successful surgical and psychological results.²⁷ All these factors influence patients'

quality of life. The latter must be assessed by means of previously validated questionnaires, such as the B-OQLQ, before treatment onset, so as to determine the condition's level of influence on patient's quality of life and how such condition can be improved in order to ensure patients' satisfaction, reestablishing his health as a whole and, thus, justifying the biological/financial costs the patient had in both public and private instances.

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- Must comprise the title, abstract and keywords.
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3. Abstract

- Preference is given to structured abstracts with 250 words or less.
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- Digital images must be in JPG or TIF, CMYK or grayscale, at least 7 cm wide and 300 dpi resolution.
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- The author(s) must ascertain that all figures are cited.

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- Files containing the original versions of graphs and tracings must be submitted.
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- Tables must be self-explanatory and should supplement, not duplicate the text.
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- Articles must, where appropriate, refer to opinions of the Ethics Committees.

9. Required statements

All manuscripts must be accompanied with the following statements, to be filled at the time of submission of the article:

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10. References

- All articles cited in the text must appear in the reference list.
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Articles with one to six authors

Sterrett JD, Oliver T, Robinson F, Fortson W, Knaak B, Russell CM. Width/length ratios of normal clinical crowns of the maxillary anterior dentition in man. *J Clin Periodontol*. 1999 Mar;26(3):153-7.

Articles with more than six authors

De Munck J, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M, et al. A critical review of the durability of adhesion to tooth tissue: methods and results. *J Dent Res*. 2005 Feb;84(2):118-32.

Book chapter

Higuchi K. Osseointegration and orthodontics. In: Branemark PI, editor. *The osseointegration book: from calvarium to calcaneus. I. Osseointegration*. Berlin: Quintessence Books; 2005. p. 251-69.

Book chapter with editor

Breedlove GK, Schorfheide AM. Adolescent pregnancy. 2nd ed. Wiczorek RR, editor. White Plains (NY): March of Dimes Education Services; 2001.

Dissertation, thesis and final term paper

Kuhn RJ. Force values and rate of distal movement of the mandibular first permanent molar. [Thesis]. Indianapolis: Indiana University; 1959.

Digital format

Oliveira DD, Oliveira BF, Soares RV. Alveolar corticotomies in orthodontics: Indications and effects on tooth movement. *Dental Press J Orthod*. 2010 Jul-Aug;15(4):144-57. [Access 2008 Jun 12]. Available from: www.scielo.br/pdf/dpjo/v15n4/en_19.pdf.

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 with 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 the existing clinical trials at different stages of implementation with links to their full description in the respective Primary Clinical Trials Register.

The quality of the 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 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, the registered clinical trials will be forwarded to those recommended by WHO.

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

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

- Primary Registers: Comply with the minimum requirements and contribute to the portal;
- Partner Registers: Comply with the minimum requirements but forward their data to the Portal only through a partnership with one of the Primary Registers;
- Potential Registers: Currently under validation by the Portal's Secretariat; do not as yet contribute to the Portal.

3. Dental Press Journal of Orthodontics -

Statement and Notice

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