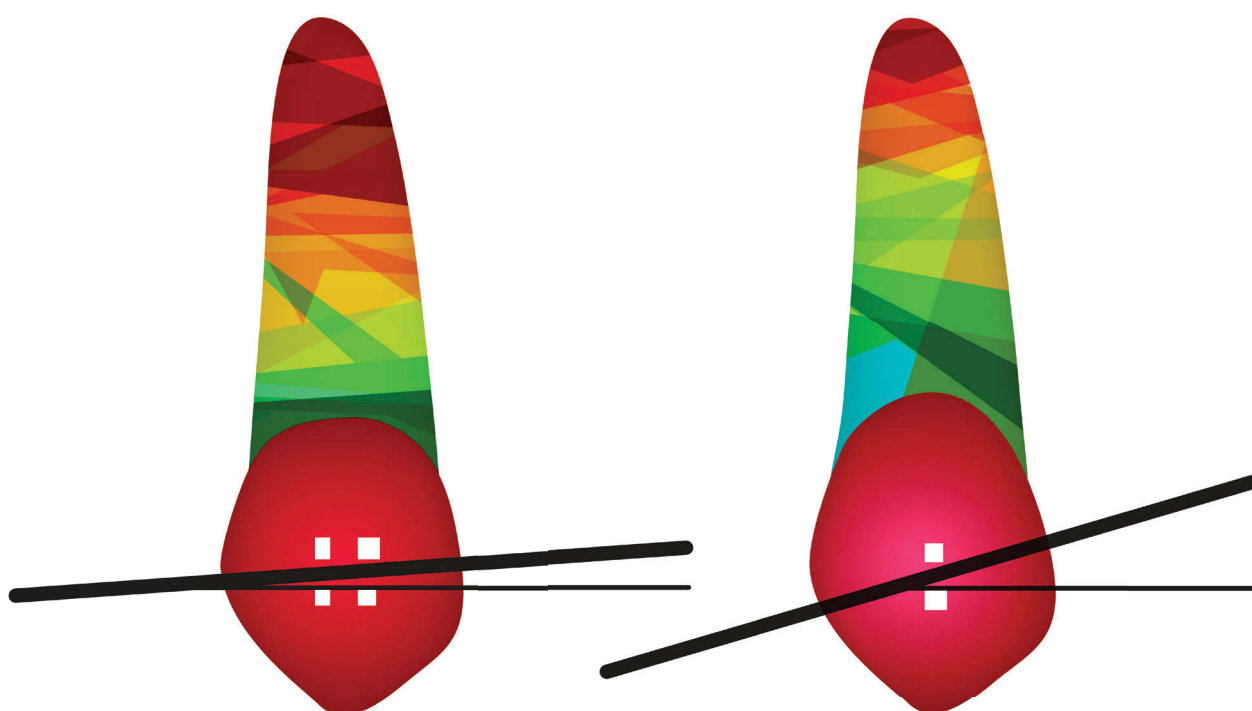


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The statistics of a clinical case

"It is easy to lie with statistics. It is hard to tell the truth without it."

Andrejs Dunkels

Some interesting discussions have been observed, in social networking, what is preached as an excessive appreciation of researchers for statistical analysis, in lieu of clinical experience. As a clinician and researcher with some learning in statistics, I believe it is a mistake to separate the two issues.

Recently, a 14 year-old patient who came to me for orthodontic retreatment, presented in the routine radiographic records a radiolucent image with clear borders and approximately 1 cm in diameter. Immediately I asked for a pathologist evaluation, who, facing an imminent suspect of idiopathic bone cavity, or traumatic bone cyst, recommended a biopsy. The histological examination confirmed the diagnostic hypothesis. It was indeed a cyst. Her mother said that the remote probability of a neoplasia brought concern to friends and family. She had heard a similar story from a friend whose teenage daughter also would have used braces. The mother's logic had caused the following inference:

"- So, Doctor... I think the use of these appliances is causing these injuries. Look, two teenagers and these images were detected in both."

I explained to the mother that, despite the logical observation, we cannot prove this cause-effect relationship imagined, only with the data reported. That's because she should take into consideration that it is normal for all patients who wear braces to take X-rays often and therefore it is more likely to detect such findings in subjects who underwent orthodontic treatment — simply because they take more X-rays. The X-ray, in turn, facilitates the discovery of a bone injury, a fact already reported.¹ Orthodontic treatment seems to be, moreover, a confounding factor and at least for now, science is lacking in well designed studies on this relationship.

The situation described above illustrates how the human mind is set to find the order, even where there is none. Our mind was built to identify a definite cause for every event, and find it hard to accept the influence of unrelated or random factors. This false logic can lead us to take wrong decisions. Unfortunately, this is the pattern of observations when we consider only our own clinical experience to decide therapy. The fatality of error will be greater the lower our sample is (i.e., clinical experience). Our brain, by several factors, does not have the ability to eliminate the confounding factors associated with a phenomenon. For this reason we appeal to the aid of statistics. But we cannot deceive ourselves, it also does not represent the end of the road and, often reaffirms the thought of Dunkels, in the title.

The hypothesis to be tested should examine, through a well-designed study, the incidence of bone cysts in a group of individuals who received orthodontic treatment, and compare them with a control group without orthodontic intervention. After the data collecting, the results would require a statistical approach to define what is the probability of the observed difference between groups not having occurred by chance — or, in other words, that the association between the incidence of cysts and orthodontic treatment is actually true. In statistics, the probability of a fortuity (or the difference to be a lie) is measured by the p value, present in almost all scientific studies. Therefore, the smaller the p value is, the smaller the chance of error in stating the association.

Of course, the experience accumulated over the years of clinical activity should not be thrown away. In fact, it is estimated that only 15% of our clinical decisions are supported by scientific evidence.

Therefore, most of the attitudes are taken based on the clinical routine, or what we have been transmitted by our tutors. Science itself, which is settled into solid methods, has been in some battles on the decision about what is more appropriate for a given clinical situation. If we consider solely the opinions held by clinical experience, it increases our probability of error, the same p value. In other words: our truth being, in fact, a lie.

As an orthodontist, with some clinical experience, and a researcher, with some learning in statistics, I believe that the best evidence is not a single study, even a randomized clinical trial, the highest level of evidence from primary studies. Depending on the fact, I consider that, despite its importance, the clinical experience alone is not the best guideline for better treatment in an individual case. Thus, it is not A or B, but the sum $A + B$. The union of scientific knowledge, derived from the best available evidence — and therefore, with appropriate statistics —, and the consolidated clinical experience produces the greatest chances of success when treating a particular patient.

Thus, for younger people, while clinical experience walks slowly, you better hurry up and keep up

to date. Enjoy the wealth of scientific research and eminent masters using this *modus operandi*. For the more experienced clinicians, scientific reading permits a reassessment of its regression or clinical procedures performed on a daily basis, and the identification of the infamous confounders. After all, as the French philosopher Diderot stated: “He who examined himself is truly advanced in the knowledge of others.” So you have to learn to question your own beliefs. Spend time searching evidences that prove you are wrong, also search for reasons that show how much you’re right. This approach will give you a lower chance of error when treating your next patient. However, consider that this is only the thought of a perpetual learner, who at this time already started doubting his own convictions.

Have a nice reading!

David Normando - Editor-in-chief
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The future of dentistry: How will personalized medicine affect orthodontic treatment?

Gustavo Zanardi¹, William R. Proffit², Sylvia A. Frazier-Bowers³

Scientists are rapidly developing and employing diagnostic tests in medical diagnosis based on genomic, proteomics and metabolomics to better predict the patients' responses to targeted therapy. This field termed 'personalized medicine' combines human genome, information technology, and biotechnology with nanotechnology to provide treatment based on individual variation versus population trends.^{1,2} Similarly, within the last 30 years, orthodontists have seen the introduction of modern appliance designs, digital records, advanced imaging capabilities, and the integration of soft tissue esthetics into diagnosis and treatment planning. It is relatively easy to see how these introductions have advanced the specialty. However, when considering the influence of genetics on contemporary orthodontics, the advances are perhaps not as obvious. The views presented here are based on the central tenet that applying genetic knowledge to the field of orthodontics will augment the current differential diagnosis of malocclusion, permitting recognition of different types of malocclusion that are etiologically discrete and so might respond to treatment in different ways.

This would undoubtedly change the way clinicians choose therapeutic modalities in the future.

The significance of genetics in malocclusion has been known for centuries and has always been a topic of great debate and some controversy. Lundstrom³ and others⁴⁻¹⁰ examined the question of 'nature versus nurture' and found that both influenced the development of malocclusion to some extent, with genetics accounting for up to 50% of malocclusion. In a recent study, Normando et al¹¹ suggested that genetics plays the most important role and prevails over environment on dental malocclusion etiology. Those findings, however, were different from many studies of European-derived population groups. Regardless of whether an environmental versus genetic component prevails, as a result of the Human Genome Project we have witnessed an explosion of molecular advances that is influencing a paradigm shift toward a genetic etiology for many developmental problems, including those that are craniofacial. In this article, we will explore the relationship between genetics and malocclusion from both the historical and contemporary perspectives.

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FUTURE DIRECTIONS IN CLINICAL ORTHODONTICS AND GENETICS

Currently the diagnosis and treatment of most types of malocclusion is fraught with inconsistencies concerning the timing, duration and type of treatment. For example, the decision of whether to treat early a patient with Class III malocclusion, with growth modification, camouflage orthodontically or prescribe a surgical approach can often present a dilemma for both the clinician and patient. The appropriate choice of treatment is often limited by the specific 'subtype' of Class III malocclusion presented, with reverse pull headgear or a chin cup being contraindicated in certain patients. Therefore, the first and most critical step in the application of genetics to clinical orthodontics must be to develop a comprehensive and detailed phenotypic categorization, which can subsequently be correlated with results from genotyping experiments.

Within the spectrum of orthodontic problems that are suspected to have a genetic etiology, Class III malocclusion provides a good example of a malocclusion that orthodontists acknowledge as genetic in origin. However, the knowledge that Class III malocclusions in many cases possess a genetic etiology does not lessen the challenge in diagnosis and treatment planning. The questions of 'when and how' to treat are still problematic. This is due in part to a more general problem in clinical orthodontics; specifically that much of the diagnostic process, particularly that based on cephalometric analysis is quite controversial.¹² To address some of the gaps in knowledge and understanding, one attractive proposal would be to develop a system whereby an objective and detailed characterization of malocclusion into specific subtypes (beyond Angle's classification) that could be correlated with specific haplotypes. Using Class III malocclusion as a model for this exercise, the range of the Class III phenotype should be carefully characterized first delineating, for example, between individuals with a Class III relationship as measured by some antero-posterior (AP) determinants such as ANB and overjet, versus those who have a vertical component, such as downward and backward rotation of the mandible masking the AP problem. Clearly many different subtypes exist and may include

variation in location and severity of the component distortions. Once these 'subtypes' of Class III can be fully characterized they can then be compiled to determine how the phenotypic subtypes (sub-phenotypes) are inherited within families.

The question is: 'Is there a gene for mandibular prognathism?' Almost certainly multiple genes interact in the development of this condition, just as they do for other aspects of growth. Studies have shown that discrete genetic locations are associated with Class III malocclusion, specifically mandibular prognathism¹³ and maxillary deficiency.¹⁴ Another more recent study¹⁵ found that a genetic variation of the protein Myosin (Type I) contributes to mandibular prognathism, which suggests that muscle function might have a more important role than previously thought in the development and deviations of the bone structures of the craniofacial complex. In addition, it is quite likely that the expression of genes is different depending on the subtype of this problem. Today's researchers have at their disposal many techniques to successfully map genes, and the success of these methods in identifying the genetic basis of congenitally missing teeth is impressive.¹⁶ A similar strategy can be applied toward unraveling the genetic basis of mandibular prognathism. Mouse studies already have shown that distinct quantitative trait loci (QTL) determine the shape of the mandible.¹⁷ As it becomes clearer what genes are involved in excessive mandibular growth, it is highly likely that genetic analysis will contribute to our knowledge of how to manage this problem. Knowledge of the type of craniofacial growth associated with specific genetic variations could help greatly with both the type and timing of orthodontic and surgical treatment.¹⁸

Studies in tooth eruption also provide compelling evidence of a genetic etiology in malocclusion, specifically eruption disorders. Molecular studies have revealed that eruption is in fact, a tightly coordinated process, regulated by a series of signaling events between the dental follicle and the alveolar bone.¹⁹ A disruption in this process can occur as part of a syndrome or as a non-syndromic disorder (isolated or familial) ranging from delayed eruption²⁰ to a complete failure of the primary eruption

mechanism itself.^{21,22} Recently, reports of genetic alterations in the parathyroid hormone receptor 1 (PTH1R) gene^{19,23} further confirmed the molecular basis of tooth eruption; a mutation in the PTH1R gene results in a striking failure of eruption that is hereditary (typically observed as a posterior lateral open bite). This finding is significant for many reasons including: (1) as non-syndromic eruption disturbances are difficult to distinguish from one another (i.e. ankylosis versus PFE or primary retention versus PFE), the knowledge of a genetic cause for some eruption disturbances will undoubtedly help delineate between the diagnoses of eruption disorders stemming from a local versus systemic cause; and (2) establishment of a genetic cause for eruption problems will facilitate a more accurate diagnosis and hence appropriate clinical management of the problem. That is, awareness of an eruption failure due to a genetic mutation in a given patient is certainly an indication that treatment with a continuous archwire should be avoided, as it will only worsen the lateral open bite.²²

The deciphering and analysis of the human genome signal the inception of a new era of gene-based medicine. During the next several decades, many of the current materials and methods may be abandoned in favor of emerging bioengineered technologies, genetically programmed for the prevention and treatment of oral disease as well as for the repair of damaged dental tissues. The development and implementation of these innovative dental therapies will require intensive education of

current practitioners. Considerable restructuring of dental school curricula will need to take place, and the emergence of a new dental specialty is anticipated.²⁴ Keys to successful treatment outcomes include knowing how different patients respond to various treatment modalities, and how the natural history of many skeletal and connective tissue disorders impact short and long-term orthodontic treatment outcomes. In the more distant future, linkage studies that lead to the identification of specific genetic mutations responsible for certain malocclusion will form the basis for future studies that create specific drug targets to correct discrepancies in facial growth. With the rapid progress made in human molecular genetics and the knowledge gained from the HapMap and Human Genome Projects, we can envision a time when specific haplotypes are linked to distinct sub-phenotypes such as those seen in Class III malocclusion. If we can successfully categorize individuals based on subtypes, then we can start to propose sensible experiments or clinical trials to identify appropriately targeted clinical treatment (i.e. personalized medicine in orthodontics). Further, genetic screening tools whereby a saliva or buccal cell (cheek swab) sample is taken at the initial records visit can be used for diagnosis and to predict predispositions to iatrogenic consequences in patients. In any case, as the field of orthodontics continues to develop technologically and philosophically, we can expect that advances in diagnosis and treatment planning are eminent and inevitable.

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an interview with

Hugo De Clerck

- Hugo De Clerck is a graduate of the Rijksuniversiteit Gent's orthodontic program, he received his PhD in 1986 and he maintains a private practice in Brussels. He received the European Research Essay Award in 1988. He has been Professor and Chairperson of the Department of Orthodontics at the Université Catholique de Louvain from 1989 to 2006. Currently he is Adjunct Professor at the University of North Carolina at Chapel Hill. He is the former President of the Belgian Orthodontic Society and Fellow of the Royal College of Surgeons of England. His main research interests are in skeletal anchorage, biomechanics and orthopedics. He lectured extensively on these topics throughout the world.

There are rare moments in which one can be present in a revolution, a paradigm shift or a promising discovery. If we place this fact into our professional universe, chances are even smaller. Faced with a novelty, we may note optimistic reactions by some, and skeptical by others. The optimists are avid to learn and use the novelty, desiring to offer comfort to those they can be of help. On the other hand, the skeptical, suspiciously, prefer that the optimistic try first, make their mistakes first, so that, afterwards it is worthy to leave their comfort zone – if possible, while the new is not yet old. If you are an optimist or a skeptical, one thing I guarantee: It is impossible to read this interview without becoming a witness of orthodontic history.

Bruno Furquim

» Patients displayed in this interview previously approved the use of their images.

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What are the treatment effects on the maxilla produced by your approach to Class III treatment? How does this approach differ from the use of a face mask combined with a bonded palatal expansion device? (James McNamara)

Bollard miniplates are inserted on the left and right maxillary buttresses and between the canine and lateral incisor on both sides of the mandible. Intermaxillary elastics are fixed between the upper and lower plates 24 hours a day. The application of a continuous forward traction on the maxilla results in a stretching of the fibers in the sutures and stimulation of bone apposition. Because of the complex interdigitations in the zygomatico-maxillary suture the resistance against the opening of this suture is greater than when separating the zygomatico-temporal and zygomatico-frontal sutures. This may explain why both halves of the maxilla and the left and right zygoma move forward as one unit. This has been demonstrated by the superimposition of a CBCT from the start of orthopedic traction and another after one year, registered on the anterior cranial base. The effects on the pterygo-maxillary complex are difficult to be evaluated in 3D images. However there is some evidence that supports the hypothesis that the weak transverse palatine suture, rather than the tight connection between the pyramidal process of the palatine bone and the pterygoid plates of the sphenoid bone, may be affected by the orthopedic traction. This was also observed in several maxillary protraction studies on monkeys in the late 70's.

In a sample of 25 consecutive patients treated with bone-anchored maxillary protraction, the maxilla was displaced 4 mm more forward, compared to a control group of untreated Class III patients. Also compared to a matched sample of patients treated with face mask after rapid maxillary expansion (RME), the amount of forward displacement/modeling of the maxilla was significantly greater. The continuous elastic traction may result in more bone formation than the intermittent forces generated by a face mask. Another difference compared to face mask therapy is the skeletal anchorage applying the forces directly on the bone surface of the jaws. Even when a bonded palatal expansion device is used as anchorage for the face mask, this will result in some proclination of the upper incisors and dentoalveolar compensation



of the skeletal Class III. With our approach, no dental compensations of the upper incisors were observed, but some spontaneous proclination of the lower incisors occurred. Furthermore, we very exceptionally do a rapid maxillary expansion prior to the orthopedic intermaxillary traction. Mild crossbites are spontaneously corrected following the correction of the skeletal Class III. When comparing our results with the results of face mask therapy combined with RME, part of the overall effects of the face mask should be attributed to some forward projection of the anterior nasal spine during rapid maxillary expansion.

In maxillary protraction cases with Bollard miniplates, which force and time protocols do you recommend, both for correction and for retention? (Adilson Ramos)

We only tried out one single loading protocol. As we were satisfied with the initial results, we preferred to maintain the original protocol, in order to get a homogeneous sample. Originally we started with light forces, mainly to avoid overloading of the upper

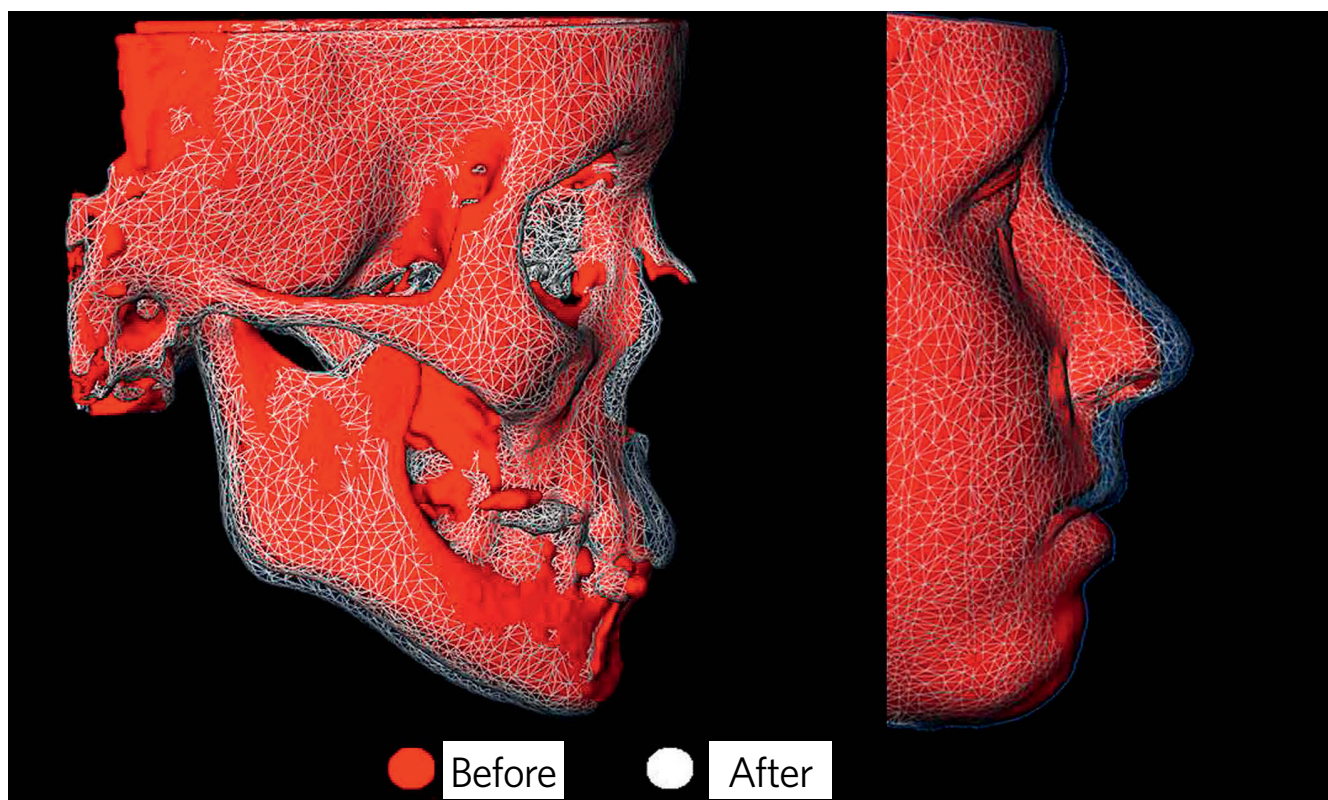


Figure 1 - CBCT before (red) and after (transparent mesh) one year after orthopedic traction, registered on the anterior cranial base.



Figure 2 - Occlusal changes after one year of bone-supported intermaxillary orthopedic traction.

miniplates. Even with light forces, a good improvement of the Class III malocclusion is generally observed in the early stage of treatment. For this reason we advise to start with a loading of about 100 grams each side. Often a 5/16-in elastic is used, however the choice of elastics depends on the distance between the upper

and lower plate, which is related to the severity of the skeletal Class III and the A-P position of the upper Bollard miniplates, depending on the inclination of the infrazygomatic crest. During the next three months we gradually increase the force level to 1/4-in and 3/16-in elastics. We ask the patient to augment

the force a week before his next visit, so that we can change the loading shortly after the upgrade if there is increased mobility of the anchors. The patient is instructed to replace the elastics at least twice a day. The final loading is definitely smaller than generally used in combination with a face mask. Nevertheless, the orthopedic outcome is better. This may be explained by the intermittent force application with a face mask, also depending on the compliance of the patient. The wearing of the elastics is easier accepted by these young patients than the social impact of an extraoral device. The loading is started no later than 2 to 3 weeks after surgery and it is maintained for a total period of one year.

What is the force level used with the bone anchors? What happens if a higher force is applied?
(James McNamara)

We are not sure that higher forces result in more growth changes. But, high forces may exceed the maximal resistance of the external cortical plate of the infrazygomatic crest and lead to bone loss and loosening of the screws. For this reason we don't use forces higher than 200 grams.

What are your clinical impressions on the stability of Class III maxillary protraction cases? In the correction of Class III which precautions do you recommend at the retention stage? (Adilson Ramos, Maurício Sakima)

There is a huge variability in growth changes of the midface observed during the active period of the orthopedic treatment. This may be due to different levels of interdigitation of the maxillary sutures, which are not always related to the chronological age. After the active orthopedic treatment the expression of Class III growth will further continue and will lead to relapse. Also an important interindividual variability is seen in the amount of remaining Class III growth during the retention period until adulthood. For this reason the miniplates are not removed after active treatment. They are used for night time intermaxillary traction when a relapse tendency of the Class III malocclusion is observed. Some cases hardly need any extra intermaxillary traction after the active period, others need more. Although treatment is started two to three years later than conventional

face mask therapy, the follow-up takes a long time and total observation time is much longer than for conventional orthodontic treatment.

Which percentage of patients treated in this way had to undergo orthognathic surgery later on?
(Maurício Sakima)

The majority of the patients in our sample didn't reach the end of facial growth yet. Moreover, the need for orthognathic surgery will be difficult to define. On one hand we will have the evaluation of the orthodontist and the surgeon about the severity of the remaining Class III soft tissue profile compared to a commonly accepted norm. On the other hand, the personal opinion of the patient, based on his self-esteem, will be crucial to decide whether surgery will be done or not. His self-esteem will be influenced by his experience that during growth already some improvement of his facial expression has been obtained. In the cases where orthognathic surgery is still needed, the question will remain in which degree the orthopedic treatment was able to reduce the severity of the Class III malocclusion and to reduce the amount of repositioning of the jaws needed during orthognathic surgery.

In cases with mild Class III mandibular asymmetry is there any special care needed or you do not recommend this approach? (Maurício Sakima)

True mandibular asymmetries are usually due to an asymmetric growth potential of both condyles. Based on the literature, there is little evidence that the amount of condylar growth can be permanently modified by orthopedics. For this reason we initially excluded true mandibular asymmetries from our study. However our findings showed that more than 40% of the A-P changes in the growth of the midface are due to modifications in the mandible and glenoid fossa. Therefore, more research is needed to investigate if unilateral elastic traction is able to reduce asymmetry of the mandible and chin deviation.

What surgical procedures for miniplate insertion are particularly important, as well as hygiene and medication, in order to minimize patient discomfort? (Adilson Ramos)

The surgical procedure is a very important factor in determining the failure rate. In contrary to the

surgical protocol for insertion of miniscrews, a small mucoperiosteal flap has to be made. In the upper jaw the miniplate is positioned just in front of and parallel to the infrazygomatic crest. Further away from the crest, the external cortical bone is thinner. The device is positioned so that the round connecting bar of the neck penetrates the soft tissues in attached gingiva, close to the mucogingival border. Furthermore, the lower part of the neck should be in tight contact with the alveolar bone surface. In the lower jaw the miniplate is fixed between the lateral incisor and the canine. As a rule, no antibiotics or anti-inflammatory medications are prescribed. The patient is instructed to apply ice after surgery to reduce swelling, and to rinse with chlorhexidine twice a day for 12 days and several times a day with sparkling water. The first week after surgery the patient covers the intraoral extension with wax. This reduces mechanical irritation of the lip until the swelling is resolved. Ten days after surgery, the orthodontist gives appropriate hygiene instructions on how to clean the bone anchors with a conventional soft tooth brush. Before surgery and immediately after, the patient should be instructed not to touch the miniplate repeatedly by pressuring the tongue or fingers. This is the main reason why during the first weeks after surgery some mobility of the anchors may occur, without local signs of infection. Because of the smooth surface of this new object in the mouth, patients are tended to touch it repeatedly with the tongue. To reduce the adverse effects of these intermittent forces on the stability of the anchor, loading by elastics should be started no later than 2 to 3 weeks after surgery.

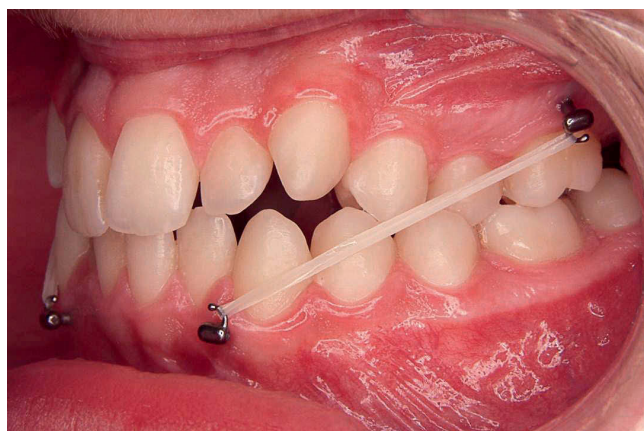


Figure 3 - Bollard miniplates emerging at the attached gingiva.

What are the limitations of the bone anchor protocol? Can this protocol be used in younger children? (James McNamara)

Two factors determine the ideal age to start treatment: The interdigitation degree of the sutures and the bone quality at the infrazygomatic crest. The “adaptability” of the growth potential in the sutures decreases with age. This may be explained by an increasing complexity of interdigitation of the sutures and increasing resistance against mechanical disruption. For this reason face mask therapy is usually recommended before the age of 9 years. However, at this age the thickness of the bone in the maxilla is not sufficient to obtain a solid mechanical retention of the screws. Based on our clinical experience, the best age seems to be around 11 for girls and 12 for boys. Starting the treatment two or three years later than conventional face mask therapy has the advantage that the final treatment with fixed appliance can be started immediately after the orthopedic correction. The follow-up period until adulthood will also be several years shorter.

What is the failure rate of miniplates in the maxilla in patients aged between 10 and 13? We often have bad quality bone in this region? Are these plates placed under sedation? (João Milki Neto)

In a recent study we investigated the failure rate of the Bollard miniplates in 25 consecutive Class III growing patients. They were all inserted by the same experienced surgeon. Sedation is not commonly used in Europe. Therefore, most of the miniplates were placed under a short general anesthesia (outpatient care).

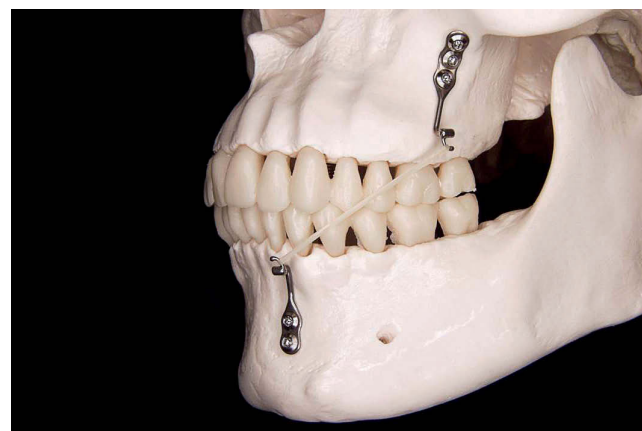


Figure 4 - Elastics are fixed between the miniplates in the infrazygomatic crest and the other in the lower canine region.

On a total of 100 miniplates one could not be fixed because of poor quality of the bone and insufficient mechanical retention of the screws. It was inserted three months later under local anesthesia and could be further used without problems. Five miniplates became loose after loading during the first three months. By interrupting the elastic traction, two bone plates became fixed again. However three had to be removed. After a healing period of about three months, the miniplates have been reinserted under local anesthesia and could be used again for intermaxillary traction. This high success rate is obtained by an experienced surgeon and orthodontist. However there is a learning curve for the surgeon to become familiar with the surgical protocol and the orthodontist has to learn how to deal with increasing mobility of some anchors and how to adapt the loading protocol.

Are there many cases that do not complete therapy because of complications? What are the most common technical problems encountered with your technique? (Jorge Faber/James McNamara)

The most common technical problem is loosening of the miniplate, mainly in the maxilla, in case of poor quality bone. Exceptionally a fracture of a miniplate can occur. This mainly happens after excessive bending of the round connecting bar during the surgical procedure. If a miniplate is lost, it can be replaced under local anesthesia and treatment can be completed.

Considering the timing of your treatment protocol, does the option of Rapid Maxillary Expansion + Face mask remains valid in early mixed dentition? (Leopoldino Capelozza Filho)

Because the different age range, face mask combined with RME can be started in the mixed dentition and if the outcome is not sufficient, a bone-anchored traction can still be started on a later age. However we have no evidence yet that a treatment in the early mixed dentition with RME/FM followed by a bone-anchored orthopedic treatment several years later has a better outcome than a bone-anchored orthopedic treatment alone. Then, such a two phase

treatment should be avoided in order to reduce costs and discomfort for the patient.

What are the effects of the intermaxillary traction on the mandibular growth?

(Leopoldino Capelozza Filho)

Besides the effects on the maxilla, the forward projection of the chin was also affected. Compared to a control group, nearly 3 mm difference in forward displacement/modeling of the bony chin was observed. However, the increase in length of the ramus and body of the mandible was not significantly different between our sample and a control group. It was concluded that the shape, rather than the size, of the mandible was modified by the continuous elastic traction. A closure of the gonial angle and posterior displacement of the ramus together with some modeling processes in the glenoid fossa are the basic effects of the force application on the mandible. In contrary to face mask therapy, no clockwise rotation of the mandible is observed. Open rotation of the mandible also results in a backward displacement of the chin, which contribute in the improvement of the facial convexity by face mask therapy.

Could adult patients benefit from this protocol when used in conjunction with surgically assisted rapid maxillary expansion (SARME)?

(Bruno Furquim)

We have no experience with this procedure. The purpose of this treatment is completely different. Instead of distracting sutures, the maxilla is protracted at the level of the corticotomy. It's not sure that the light elastic traction is able to move the maxilla sufficiently forward. Moreover there will be poor vertical control and no precision in the final positioning of the maxilla, and of course no mandibular effects can be expected. If a SARME is indicated to correct a transverse deficiency of the maxilla and if also a forward displacement of the maxilla is needed, why not extending the surgical procedure by a Le Fort I osteotomy and down fracture, and position the maxilla in the 3 dimensions in an optimal relation with the rest of the face?

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Advances in knowledge about induced tooth movement

Part 1: The osteocytes

Alberto Consolaro¹

Osteoblasts and clasts were primary targets for the understanding of bone biopathology. In recent years, evidence has shifted attention to the osteocytes. The biology of induced tooth movement and jaw orthopedics should research the role of osteocytes and the specific effects of mediators such as RANKL and sclerostin. The sclerostin represents a regulatory molecule: When more bone is necessary, osteocytes release less sclerostin, when it is necessary to inhibit bone formation, osteocytes release more sclerostin. RANKL is connected to local osteoclastogenesis in order to have more cells capable of reabsorbing the mineralized matrix. New therapeutic ways of controlling the metabolic bone diseases have been targeted at these mediators.

Keywords: Osteocytes. Mechanotransduction. Tooth movement. Sclerostin. RANKL.

The osteocytes have always been placed in a second role in the study of the phenomena associated with tooth movement, as well as in bone biology and comprehension of the diseases involving our skeleton. It was believed that osteocytes were included in the mineralized bone matrix and, thus, did not participate in bone metabolism, the responses to stimuli and aggression.

The dendritic shape of the osteocyte puts it in contact with 40 to 50 cells simultaneously, generating among them a very efficient communicating network, while scavenging any deformation that the bone may suffer from deflections resulting from compression and traction. This osteocytes communicating network acts as excellent

mechanotransducers and also are centrally involved in bone metabolism by releasing mediators that reaches bone surfaces.

As shown in numerous studies over the past five years, there is strong influence of osteocytes in bone remodeling and, by extension and consequence, osteocytes must actively participate in the biopathology of the induced tooth movement, among which is the biology of orthodontic movement.

THE ORIGIN OF OSTEOCYTES: PRIMARILY MESENCHYMAL CELLS AND, SECONDARILY, DERIVED FROM OSTEOBLASTS!

The osteocytes and osteoblasts are mesenchymal cells which differentiate upon stimulation of

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mediators still in the embryo and fetus. The main mediator of differentiation and synthesizing activity in this intrauterine phase are the BMPs or osteomorphogenetics proteins. Mediators in the early stage, that determines the form of organs and structures, can be identified as morphogens, such as it is in these osteomorphogenetics proteins. In this osseodifferentiation and synthesis environment, much of the molecules of these mediators are eventually included in the bone extracellular matrix to be mineralized later. Thus, it can be assured that any mineralized bone matrix has, naturally, osteomorphogenetic proteins in its composition.

Once the skeleton is formed and adulthood is established, osteoblasts and osteocytes remain in bone environment. Many osteoprogenitor cells, pre-osteoblasts and tissue stem cells, formerly known as undifferentiated mesenchymal cells remain on bone surfaces. In the bone marrow, contained and protected by trabeculae and cortical, there are many tissue stem cells, which can originate almost infinitely new bone cells.

Osteoblasts on the surfaces of the trabecular and cortical bone, are polyhedral cells arranged side by side, like a real fence, railing, or palisade. Its polyhedral format allows, on one of its surfaces, bone matrix production, and, in the other surface, expose receptors to mediators located on adjacent connective tissue or bone marrow tissue. At the same time, laterally, osteoblasts contact and interact with other osteoblasts to form a true cell layer covering bone surfaces.

In certain conditions the osteoblasts synthesize the bone matrix and mineralize it; in other conditions, as in inflamed and stressed areas, the mediators can induce osteoblasts and move the bone surface, remain on the periphery and command the clasts activity in the context of a osteo-remodeling unit or BMU.

In this bone matrix deposition many osteoblasts eventually end up included in gaps called osteoplasts (Figs 1, 2 and 3). It was believed for many years that these cells would be trapped, almost by a passive mechanism, as if they had lost the moment to depart, and got involved in the newly deposited matrix. The passive role of osteocytes was proved untrue. On the contrary, these cells seem to perform a central role in controlling bone remodeling and opposite reactions to certain stimuli.

THE LOCATION AND SHAPE OF OSTEOCYTES

Osteocytes comprise 90-95% of bone cells in an adult.¹⁵ These cells are included in the mineralized bone matrix (Figs 1, 2 and 3) and now, as with osteoblasts and clasts, we also have greater knowledge about the osteocytes and their functions.

Osteocytes are regularly distributed in the gaps in the bone matrix, also known as osteoplasts, and communicate with each other and with the cells of the bone surface by means of extensions of the canaliculi of 100 to 300nm thickness.^{3,4,5} They form a true web with their extensions, one real network comparable to the neural network in the central nervous system (Figs 1, 2 and 3).

Within these tubules, where the cytoplasmic processes of each cell are (Figs 1, 2 and 3), circulates a fluid tissue that carries nutrients and mediators. These canaliculi with its working fluid and its extensions communicate the osteocytes with each other and interconnected with the surface cells of cortical and trabecular bone, in addition to resident cells of the bone marrow.¹⁰ This communication can be cell-cell by means of specialized junctions or mediators (Figs 1, 2 and 3).

THE BONE MECHANOTRANSDUCTORS: OSTEOCYTES

The osteocytes network form a very sensitive 3D system that uptakes bone deformities. Any change in bone form during skeleton function can be captured by this sensitive network or web of osteocytes, and extensions or mechanotransduction detection system. Exercise can increase bone structure by mechanical stimuli, initially, on this network scavenging strain.

The osteocytes individually pick up signals by mechanical deformation of their cytoskeleton. At the same time, the network in which each osteocyte participates, distributed throughout the bone structure, picks up deformations, overloads, deflections and limitations of nutrients. The deformation of the cytoskeleton, the restriction of oxygen and of nutrient stress the osteocytes, which release mediators to communicate with other osteoblasts and clasts on the bone surface and induce them to reactive or adaptive phenomena.

When we deform, compress or strain the bone as happens during orthodontic movement, we put the

osteocytes in mechanical stress and, thus, it increases the production of secreted and circulating mediators through the fluid that circulates in the canaliculi (Figs 1, 2 and 3) and from there to the respective periodontal and bone surfaces. Although included in the mineralized bone matrix in their osteoplasts, the osteocytes and its communicating network — by direct contact or mediators — can stimulate or inhibit bone formation and bone resorption in the “distant” cortical bone surface (Fig 3). The osteocytes in the bone marrow inside the bone, can influence the higher or lower production of clastic cells and osteoclastogenesis.

The osteocytes, therefore, have a strong influence in the function of bone to adapt its shape according to the determination of functional demands, changing the mechanical stimuli into biochemical events, a phenomenon known as osteocyte mechanotransduction.¹³ The osteocytes also play a role in regulating the mineral metabolism⁹ and also induce changes in the properties of bone matrix around it,¹² but these functions were already better known.

The skeleton is able to continuously adapt to mechanical loads by the addition of new bone to increase the ability to resist or remove bone in response to a lighter load or lack of use.^{6,8} The osteocytes have a high interconnectivity and are considered the bone mechanotransducers.



Figure 1- The osteocyte network participates of the cellular functional control on bone surface, such as the clasts and osteoblasts. The cytoplasmatic prolongations arrive at the canaliculi and make contact with the surface cells or act via mediators (HE; 40X).

Osteocytes increases glucose-6-dehydrogenase phosphatase after a few minutes of load,¹⁸ a marker for increased metabolism, as it occurs in cells associated with bone surface. Seconds after the applied load on the osteocytes, nitric oxide prostaglandins and other molecules such as ATP¹ are increased.

Therefore, osteocytes, when facing induced loads, have the ability to release mediators, which stimulate the precursors of clasts or osteoclastogenesis to differentiate into new clasts increasing the rate of resorption. Among these mediators the M-CSF or stimulating factor of colonies for macrophages and RANKL should be highlighted.¹⁴ It can be argued that osteocytes can command the activities of the clasts on bone surfaces according to functional demand. The set or lacunocanicular osteocyte system can be seen as a real endocrine body.⁴

THE OSTEOCYTES AND THE BIOLOGY OF ORTHODONTIC AND ORTHOPEDIC MOVEMENT

In micro-bone lesions that occur daily, osteocytes die by apoptosis, such as when the bone tissue is dried and heated. The death of osteocytes in areas with 1-2 mm damage, such as microfractures, can generate mediators that stimulate clasts, especially RANKL,⁷ a group TNF cytokine. Preserving the osteocytes is to prevent bone reabsorption and clinicians should know this information to take better care of the surgical margins in bone surfaces. In orthodontics many procedures are surgical.

An example of osteocyte preservation can be the divided flap technique in periodontal treatments, which preserves the periosteum attached on the surface. The source of nutrients in the bone are vessels of the periosteum. Preserving the periosteum means to keep alive the osteocytes so that its death does not induce the thin cortical alveolar bone resorption, leading to an undesirable dehiscence or fenestration.

Opening the periosteum inevitably leads to the death of the most superficial osteocytes, for they do not receive nutrients from broken vessels during this surgical procedure.

When the osteocytes die in bone remodeling tissue this area will inevitably be reabsorbed. Thus, the osteocytes should be preserved in the bony walls of the cavity prepared earlier to place the implants, avoiding excessive heat or improper manipulation of surfaces, since the death of osteocytes will lead to increased bone resorption at the site, which can disrupt osseointegration.

Probably some orthopedic facial responses can be explained by bone deformities produced. The responses controlled by the osteocytes can change the shape and size of the bone to adapt to new functional demands. This increasingly requires further studies.

More recently the sclerostin was discovered, a mediator secreted by osteocytes, that circulates the fluid spaces of bone, especially in tubules with cytoplasmic osteocytes extensions.¹⁶ It represents a regulatory molecule: If you need more bone, osteocytes release less sclerostin if you need to inhibit bone formation, osteocytes release more sclerostin.

The osteocytes seem to play a central role in bone remodeling.² On induced tooth movement there are bone deformations and deflections for each activation devices, especially in the interdental bone crest

and free surfaces. When moving a particular tooth to the lingual or buccal, it is known that on the outside, bone is deposited on the cortical surface.¹⁷

In induced tooth movement with biologically acceptable forces, probably the stimulus released by the network of osteocytes on the farther part of the ligament is of mediators in type and amount required for inducing bone formation, while in the periodontal surface of the alveolar bone, the osteocytes stimuli captured by the network lead to bone permeation of mediators that stimulate osteoclastogenesis and osteoclasia in the region.

In turn, in the tooth movement induced by excessive force, the osteocytes die near the hyalinized ligament along one segment. Subjacent, the surviving osteocytes release mediators, which stimulate the underlying and peripheral osteoclastogenesis, as RANKL, while release more sclerostin to inhibit bone formation at the site. All these phenomena are occurring in the subjacent or adjacent hyalinized periodontal space, i.e., at a distance.

These discoveries in bone biology have led to search for new therapeutic alternatives for the bone metabolic problems. Some substances are death inhibitors of osteocytes on the skeleton as a whole and so promote less resorption, for example, estrogens and their modulators, bisphosphonates, calcitonin, CD40 ligand and others.² There are still anti-scleros-

tin to help control bone loss in osteopenia and osteoporosis, the most common manifestations of various metabolic bone diseases.

CONCLUSIONS

The osteocytes form a three-dimensional network with each cell communicating with other 40-50 by numerous cytoplasmic processes arranged like a real neural network. This communication is by cell contact and interaction, but particularly by mediators released by osteocytes in different amounts depending on the mechanical stimulus captured. Bone deformation by compression and

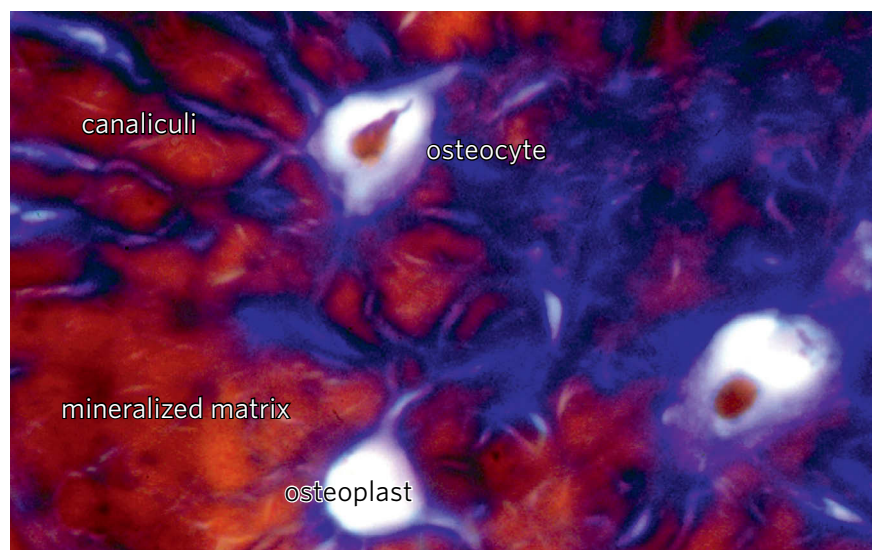


Figure 2 - The osteocytes have many cytoplasmic prolongations, which intercommunicate with the mineralized matrix with other 20 to 40-50 cells and they detect minimal structural deformations and act as mechanotransducers. They occupy lacunae known as osteoplasts and the prolongations spread out as canaliculi, where mediators circulate in a tissue fluid, which performs ionic exchange with the mineralized extracellular matrix (Mallory, 100X).

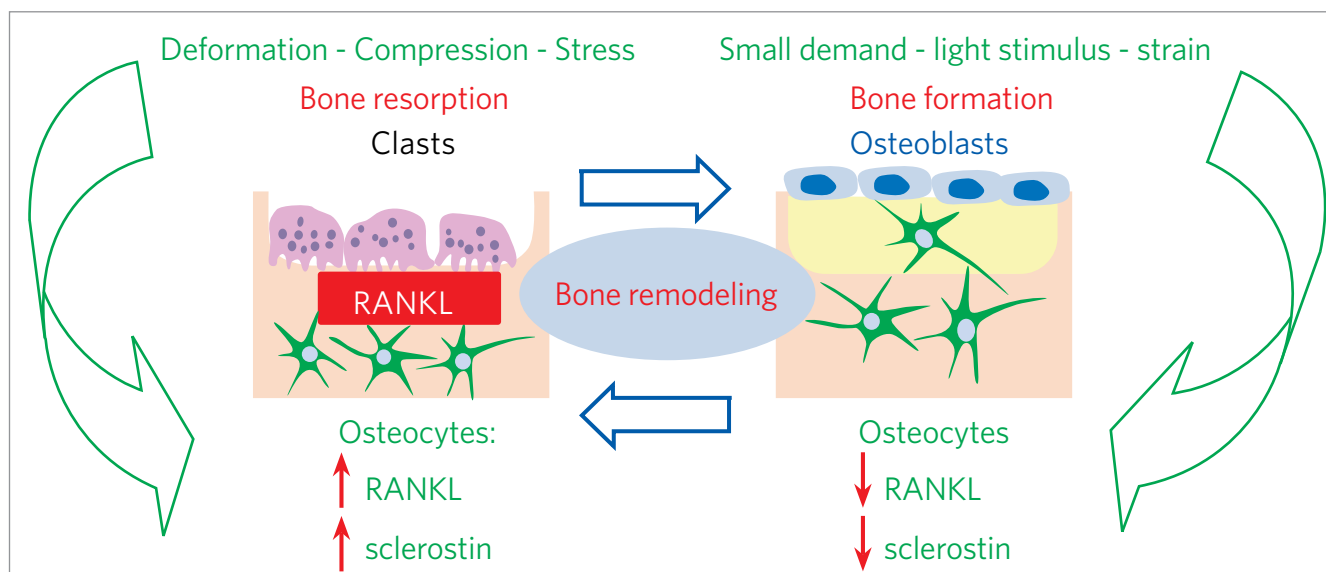


Figure 3 - The osteocytes detect shape and volume changes to increase or decrease the liberation of mediators involved in bone resorption or formation. In this manner, bone remodeling responds to the functional demand, modifying and adapting itself structurally (adapted from Nakasima et al,¹⁴ 2011).

traction during orthodontic movement stimulates these mechanisms by mediators released by osteocytes that virtually controls the formation and resorption of bone surfaces.

To study the presence and specific effects of sclerostin, of RANKL and of osteoprotegerin in the biology of induced tooth movement may represent several insights in Orthodontics and Facial Orthopedics researches.

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The orthodontist's profile in Minas Gerais

Luiz Fernando Eto¹, Valéria Matos Nunes de Andrade²

Objective: Due of the growing number of orthodontists and courses in Orthodontics, interest has grown in having a profile of these practitioners in Minas Gerais state (Brazil), showing how do they work in order to promote excellence in orthodontics, showing the most used techniques, the changes in the target public, and other views that impact on the future of the specialty and professional groups.

Methods: Questionnaires were sent to all orthodontists registered with the Regional Council of Dentistry of Minas Gerais (Conselho Regional de Odontologia de Minas Gerais, CRO-MG) until March 30, 2005, consisting of 722 professionals. Questionnaires were sent back by 241 (33%) professionals.

Conclusions: This study clarified some relevant aspects about the profile of orthodontists in Minas Gerais regarding their individuality, training and the techniques used. The patient base was composed mainly of teenagers (33.75%) and young adults (27.45%), with referral predominantly by the patients themselves (46.79%). Among the most important facts, we can mention the lack of use of some individual protection equipment, with only 37.76% using all the features of biological safety. Final exams have been requested less frequently than initial records, and findings from the literature review is even more frightening, considering the importance of these records. Looking at the future of the profession, optimistic orthodontists did not exceed half (45%) of participants.

Keywords: Orthodontics practice. Orthodontics in Minas Gerais state. Orthodontics in Brazil.

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Editor's abstract

The knowledge of a particular professional area provides important information for professionals, both in practice and newcomers, regarding the demand and manner of work, trends and changes that may occur in the target audience. The objective of this study was to evaluate orthodontists working in the state of Minas Gerais (Brazil) as far as it concerns to the occupational data, patient demand, technique, work philosophy and vision for the future of the profession. For this purpose, questionnaires were sent to all dentists registered in the Regional Council of Dentistry of Minas Gerais (CRO-MG) by March 2005, a total of 722 professionals. Of these, only 241 (33%) participated in the survey. It was observed that 71.8% of orthodontists were male, mean age of 39 years, and 75.9% were married. Most professionals (96.7%) were self-employed, and 40% of these had

more than 10 years in practice. Adolescents (10-17 years old) constituted 33.75% of patients, followed by young adults (17-30 years old) with 27.45%; children consisted of only 19.85% and adults, 18.98%. Patient referral comes mostly from the patients themselves (46.79%), followed by fellow dentists (24.26%). The Edgewise Straight-Wire technique was the most used (73.4%), 35.3% used the Standard Edgewise technique and 13.7%, Ricketts-Bioprogessive. The authors concluded that the target audience of the orthodontist in the state of Minas Gerais is comprised mostly of teenagers, and the referral of new patients occurs primarily by the patient. Moreover, the final records have been requested less frequently than the original. It should be noted that only 45% of orthodontists present themselves optimistic about the future of the profession.

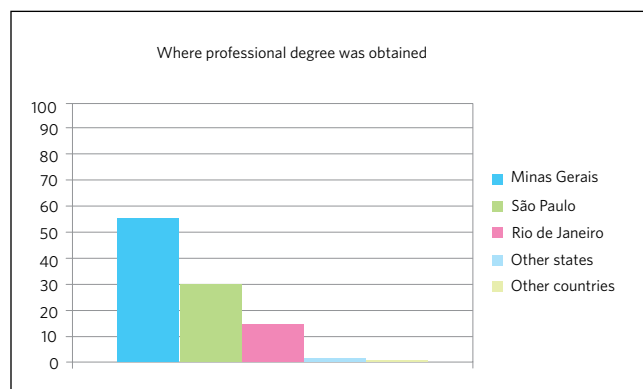


Figure 1 - Distribution of the sample according to where professional degree was obtained.

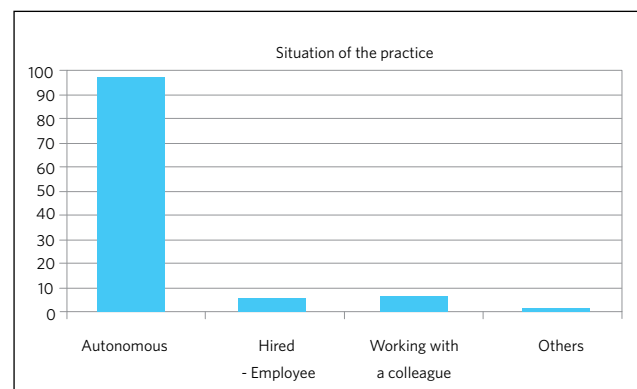


Figure 2 - Distribution of the sample according to the situation of the practice.

Quantitative assessment of *S. mutans* and *C. albicans* in patients with Haas and Hyrax expanders

Matheus Melo Pithon¹, Rogério Lacerda dos Santos², Wagner Sales Alviano³, Antonio Carlos de Oliveira Ruellas⁴, Mônica Tirre de Souza Araújo⁴

Objective: To assess and compare the number of *Streptococcus mutans* and *Candida albicans* colonies in patients with Haas and Hyrax appliances before and after insertion.

Methods: The sample consisted of 84 patients requiring orthodontic treatment. For all patients a midpalatal suture expansion was indicated. Patients were randomly divided into Group HA, who used the Haas appliance (n = 42) and Group HY, who used the Hyrax appliance (n = 42). Initially and thirty days after appliance insertion all patients were submitted to saliva collections. The saliva was diluted followed by seeding in Mitis Salivarius and CHROMagar media, for growth of *S. Mutans* and *C. Albicans* respectively.

Results: Results showed statistically significant difference between groups HA and HY for *Streptococcus mutans* and *Candida albicans* (p <0.05). Haas appliance promoted greater *S. mutans* and *C. albicans* proliferation when compared to Hyrax appliance.

Conclusion: The Haas appliance favored greater proliferation of *S. mutans* and *C. albicans* when compared with the Hyrax appliance. Insertion of the appliances resulted in greater buildup of microorganisms.

Keywords: Orthodontics. Orthodontic appliances. Streptococcus mutans. Candida albicans. Palatal expansion technique.

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Editor's abstract

Maxillary expansion presents itself as one of the most common procedures in orthodontic practice, indicated for correction of posterior crossbite and maxillary transverse deficiency. This procedure was proposed by Hass, in 1961, by means of a dental-mucous-supported appliance with an acrylic resin component in intimate contact with the patient's palate. Due to difficulty in hygiene and biofilm accumulation in this region, Biederman developed the Hyrax appliance, quite similar to Hass appliance, however with dental support only. Presumably, there would be lesser biofilm build-up using the Hyrax expander when compared to the Hass expander. With this purpose, this study aimed to compare the number of colonies of *Candida albicans* (microorganisms primarily associated with buccal candidiasis) and *Streptococcus mutans* (directly related to dental caries incidence) in patients undergoing maxillary expansion with Hyrax or Haas appliances.

The sample consisted of 84 patients with ages ranging from 13 years and 04 months to 15 years and 09 months, divided into two groups with 42 patients each, depending on the use of Hass or Hyrax appliances. Collection of 300 ml of saliva from each patient was performed before and 30 days after inserting maxillary expanders. After proper dilutions and incubation period, the counting of the number of colonies of *S. mutans* and *C. albicans* yeast was performed multiplying the number of colonies by the dilution factor. The data was subjected to analysis of variance (ANOVA) and subsequently to the multiple comparison Tukey test. The results showed a greater number of colonies of *S. mutans* and *C. albicans* in patients who used the Hass expander in comparison to the Hyrax expander ($p < 0.001$ and $p < 0.000$, respectively). The authors concluded that after insertion of Hass and Hyrax expanders, there was a statistically significant increase of *S. mutans* and *C. albicans*, with greater proliferation of these microorganisms in patients using Haas appliance.

Comparative analysis of load/deflection ratios of conventional and heat-activated rectangular NiTi wires

Fabio Schemann-Miguel¹, Flávio Cotrim-Ferreira², Alessandra Motta Streva³,
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Objective: This study compared the load-deflection ratios between 0.019 x 0.025-in rectangular orthodontic wires using 5 conventional preformed nickel-titanium (NiTi) and 5 heat-activated NiTi archwires from four different manufacturers (Abzil, Morelli, 3M Unitek and Ormco), totaling 40 archwires. The archwires were placed in typodonts without tooth # 11 and tested using a universal testing machine connected to a computer.

Results: The comparisons of mean load-deflection values of conventional NiTi wires revealed that the lowest mean-deflection ratio was found for 3M Unitek, followed by Ormco, Morelli and Abzil. Regarding the heat-activated wires, the lowest load-deflection ratio was found for Ormco, followed by 3M Unitek, Abzil, and Morelli.

Conclusion: The comparison of mean load-deflection ratios revealed that the heat-activated wires had lowest mean load-deflection ratios, and this trend was seen during all the study. However, at 2-mm deflection, mean load-deflection ratios for heat-activated Morelli and conventional 3M Unitek wires were very similar, and this difference was not statistically significant.

Keywords: Orthodontics. Orthodontic wires. Qualitative analysis.

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Editor's abstract

The nickel-titanium wires have been widely used in orthodontic practice, mainly due to the release of low and continuous forces, very useful for dental aligning and leveling. So, with the advent of low elasticity modulus wire (nickel-titanium and TMA), a trend is observed during orthodontic treatment, the variation in alloys used according to the wire caliber, leading to a possible better root torque control. However, there are few studies evaluating the force released by nickel-titanium wires of rectangular section, with the purpose of its usage for the initial dental aligning and leveling. Therefore, the objective of this study consisted in comparing the released force in different deflections by four brands of conventional and heat-activated nickel-titanium wires, with rectangular cross-section 0.019 x 0.025-in. Five upper pre-contoured conventional nickel-titanium orthodontic archwires and five heat-activated were analyzed for all the following brands: Morelli (Sorocaba, Brazil), Abzil (São José do Rio Preto, Brazil), Ormco (Orange, USA) and 3M-Unitek (Saint Paul, USA). These arches were preconditioned in environment with relative humidity of 50%, at 25 °C for 72 hours and then placed in suitable brackets in orthodontic typodonts. With a steel tip, a force of 50 N was applied in the maxillary central incisor region, buccolingual direction, using a universal testing machine (Emic-10000-003-MY). The forces released by wires were recorded in the deflections of 3 to 1 mm, in intervals of 0.5 mm. Data were recorded on the Tesc Software, version 2.0, and subjected to the

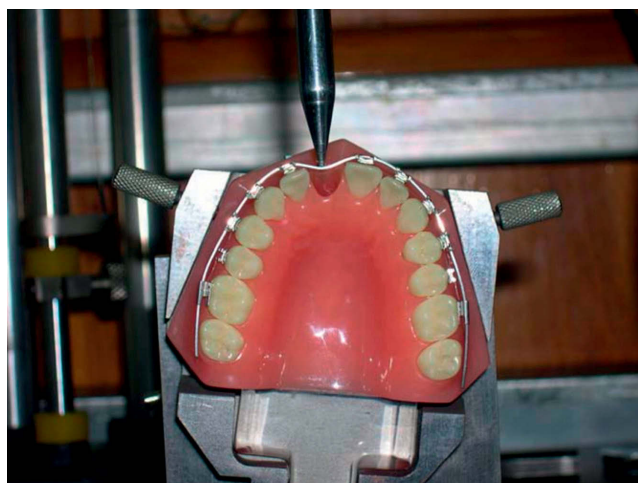


Figure 1 - Steel tip applying force in the buccolingual direction, on the upper central incisor region of the typodont.

Student's t test ($p < 0.05$). Results indicated that the heat-activated nickel-titanium wires released a minor force compared to the conventional ones, in all deflections. In comparison between brands, it was verified that there is a lower load / deflection ratio for the conventional wires for Ormco, followed by 3M-Unitek, Morelli and Abzil. Also for the heat-activated wires, a minor force was released in the different deflections for Ormco, followed by 3M-Unitek, but with the lowest scores for Abzil in relation to Morelli. The authors concluded that, in spite of the heat-activated nickel-titanium wires presenting a minor load/deflection ratio than the conventional wires, they release forces clinically non-acceptable, even in low deflections. This fact prevents the use of the rectangular nickel-titanium wires in the initial phase of dental aligning and leveling.

Influence of certain tooth characteristics on the esthetic evaluation of a smile

Andréa Fonseca Jardim da Motta¹, José Nelson Mucha², Margareth Maria Gomes de Souza³

Objective: To assess the influence of certain dental characteristics on the perception of smile esthetics by undergraduate dentistry students.

Methods: Ten digital photographs of a woman's smile were modified using Adobe Photoshop software. The following changes were performed: stain removal; incisal edge straightening; gingival leveling; closure of black triangles. A group of 60 undergraduate dental students evaluated the original photograph and the altered images using a visual analog scale to evaluate smile esthetics. Intraexaminer agreement was checked for 30 examiners using the Student t test; for casual error, the Dahlberg formula was used. Data were described as means and standard deviations, and reported in tables.

Results: There were no statistically significant differences between the first and second scores assigned by examiners ($p > 0.05$) in any of the comparisons made. The results of systematic error for the method indicated that the measures obtained were reliable. ANOVA was used to test equality of means, and the level of significance was set at 5%. Equality of variances was evaluated using Levene's test, and results revealed that variances were equal. Multiple comparisons using the Tukey's test revealed statistical significance at a 5% level for the presence of black triangular space. No significant values were found for other comparisons.

Conclusions: Some dental characteristics were perceived by undergraduate students, and the black triangular space was classified as the most unfavorable characteristic.

Keywords: Smile. Dental esthetics. Perception.

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

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Editor's abstract

One of patients' main expectations when seeking orthodontic treatment is to have a beautiful smile. Therefore, smile esthetics has become the focus of several studies that aim at defining guidelines so that orthodontists can give patients the ideal smile that they desire. Few studies have investigated how certain dental imperfections are perceived in a smile. This study investigated the effect of tooth stains (Fig 1A), irregular incisal edges (Fig 1B), unlevelled gingival contour (Fig 1C) and open gingival embrasures ("black triangles") (Fig 1D) on smile esthetics. Specific computer resources were used to add these imperfections to the digital photograph of the smile of a woman who had well leveled teeth, and two groups of photographs were produced. The first was called exclusion group, in which the original photograph was kept with all the imperfections mentioned above and four other photos were obtained from the original one, each with the correction of only one imperfection. In the second group,

called inclusion, the original photograph was fully manipulated, and all the imperfections were corrected. Another set of four photos was produced, and only one imperfection was kept in each photo. All photos were randomly evaluated by 60 undergraduate students in the School of Dentistry using a visual analog scale from zero to 100. The assessments scored by students for each photo were measured using a digital caliper. To evaluate intraexaminer agreement, 30 students reevaluated the same photos seven days later. The method error was estimated using paired Student t test and Dahlberg's formula. Analysis of variance followed by the Tukey test for multiple comparisons were used to analyze data ($p < 0.05$). Results revealed that the black triangle between maxillary central incisors was the most unaesthetic characteristic when compared with all others, and differences were statistically significant. The primary cause of black triangles may be the absence of the interdental papilla, root divergence of maxillary central incisors, or the abnormal shape of dental crowns.

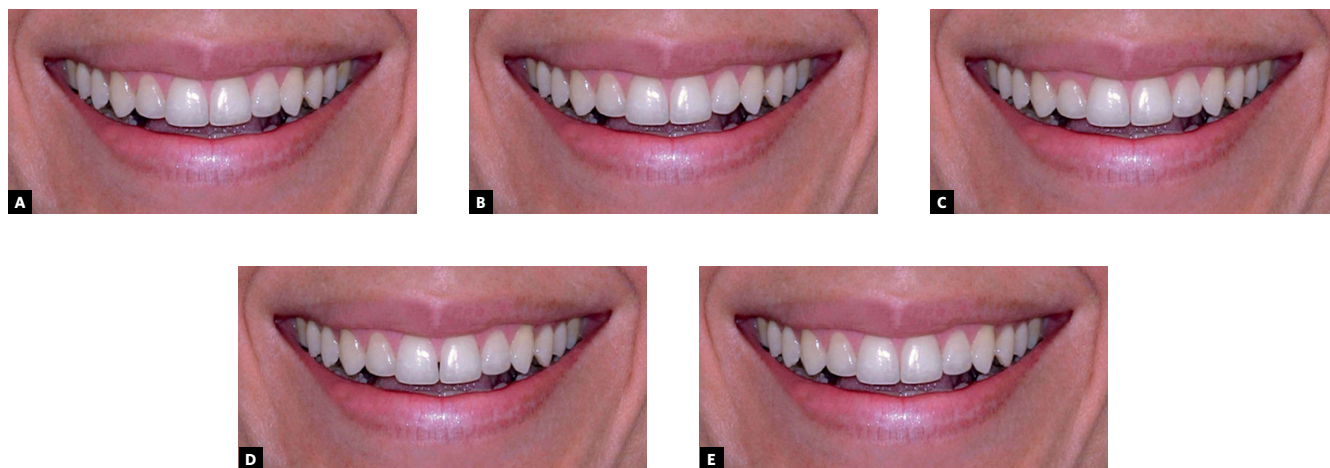


Figure 1 - Photographs used in first evaluations. **A)** yellowish stain was removed from mesiobuccal surface of tooth # 26; **B)** incisal edge of tooth # 22 was straightened; **C)** gingival margin height of tooth #12 was levelled; **D)** black triangular space between teeth # 11 and 22 was filled; and **E)** reference photograph without imperfections.

Pigment effect on the long term elasticity of elastomeric ligatures

Érika de Oliveira Dias de Macêdo¹, Fabrício Mezzomo Collares², Vicente Castelo Branco Leitune³, Susana Maria Werner Samuel⁴, Carmen Beatriz Borges Fortes⁵

Objective: To evaluate the response of elastomeric ligatures in several colors for a 4 mm traction over time.

Methods: Morelli® elastomeric ligatures, were submitted to traction forces using two rods of circular cross section, until a 4 mm distance was reached, matching the approximate diameter of an upper central incisor bracket of the same manufacturer. The ligatures were kept in artificial saliva immersion at 37 °C. Forces levels were measured immediately (0 h), 2, 4, 6, 8, 10, 12, 24, 48, 72, 96 hours, 1, 2, 3, 4 weeks and results were submitted to two-way repeated-measures ANOVA statistical analysis.

Results: The gray samples showed the higher initial values of tensile strength. The lowest values were presented by purple, light pink, green, black and red groups. The greater tensile strength instability was presented by red, black, silver, green and gray groups. The greater tensile strength stability was presented by deep pink, dark blue, blue, purple and light pink groups.

Conclusion: Elastomeric ligatures do not present stable behavior when suffering traction forces over time and different colors display different behaviors. Deep pink, dark blue, blue, purple and light pink groups, displayed the most stable forces, suggesting that they should be used during the treatment to obtain constant forces.

Keywords: Ligatures. Elastomers. Color. Elasticity.

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Editor's abstract

Elastomeric ligatures are used at the different stages of orthodontic treatment in order to pull the wire against the orthodontic brackets providing force transmission to the teeth. The elastomeric ligatures are polyurethane polymers produced by the polymerization through condensation of the di-isocyanate and polyamide crosslinked, allowing the elastic recovery to the initial spiral pattern. Although they have elastic properties, these are not considered perfect elastics, since they suffer degradation of the polymer chain leading to permanent deformation and characterizing the phenomenon called force relaxation. Pigments are incorporated into these materials in the attempt of achieving greater treatment adherence mainly by young patients. There are doubts about the mechanical properties of these materials after having been incorporated pigments. The authors' aim with this study was to evaluate the mechanical behavior of elastomeric ligatures of different colors in different intervals. For this study, we used rod-loaded elastomeric ligatures, Morelli®, in 10 different colors: light green, red, light pink, purple, deep pink, blue, dark blue, black, gray and silver ($n = 10$).

Traction of the ligatures was carried out on a universal testing machine EMIC DL 2000, with the aid of a device formed by two L-shaped rods (Fig 1). The ligatures were tensioned at a speed rate of 1 mm / sec until the inner diameter of the ligature (1.5 mm, at rest) reached 4 mm. The force (N) required to stretch each ligature was recorded immediately (0 h) and after storage periods of: 2, 4, 6, 8, 10, 12, 24, 48, 72, 96 hours and 1, 2, 3, 4 weeks. During the experimental period samples were stored in

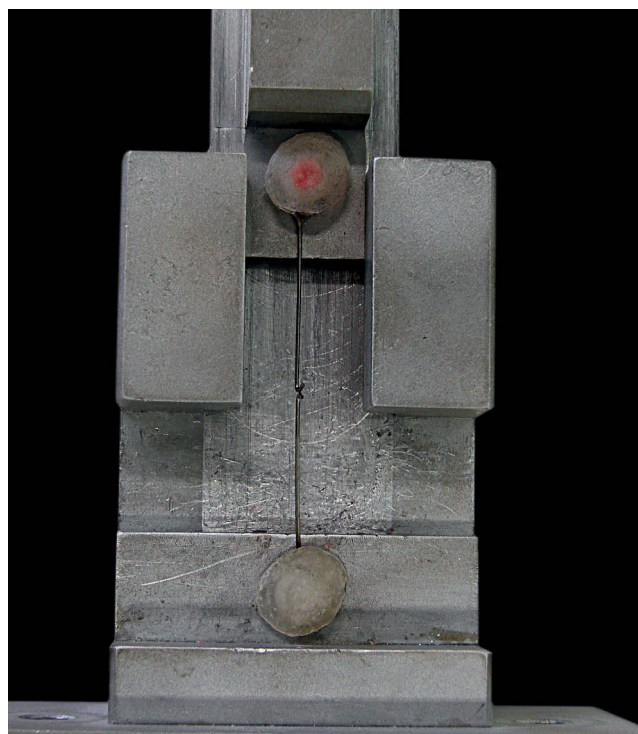


Figure 1 - Stainless steel device used to attach the ligatures during testing.

artificial saliva and incubated at 37 °C. After results were obtained, statistical analysis was carried out. Results showed that the gray pigment presented the highest initial force, and the purple, light pink, green, red and black groups had the lowest values. The greatest instability in the maintenance of forces were found in red, black, silver, green and gray groups. The most stable were the colors: deep pink, dark blue, blue, purple and light pink. The authors conclude with the completion of this work that the ligatures do not exhibit stable behavior when subjected to traction over time and that the various colors in which they are produced behave differently from each other.

Interrelation between orthodontics and phonoaudiology in the clinical decision-making of individuals with mouth breathing

Rúbia Vezaro Vanz¹, Lilian Rigo², Angela Vezaro Vanz³, Anamaria Estacia⁴, Lincoln Issamu Nojima⁵

Objective: The purpose of this study was to investigate the decision making of orthodontists of Passo Fundo district - Rio Grande do Sul (RS)/Brazil, in the Orthodontics/Speech Therapy interdisciplinary treatment of mouth breathing individuals.

Methods: The present study is a quantitative approach and the design is descriptive, using as instrument data collection of a questionnaire sent to 22 orthodontists practicing in the above-mentioned district. The project was approved by the Ethics in Research Committee and all individuals signed a free informed consent.

Results: All professionals considered the inter-relation between Orthodontics and Speech Therapy necessary, but divergences were found in situations where an associated therapy may exist, considering that 54.5% trust the inter-relation to develop aspects associated to language, oral facial motricity and habits. In cases of associated treatment, the results obtained were considered satisfactory by 73.7% of professionals, even though they consider that only 6 to 20% of their patients collaborate with treatment.

Conclusion: In relation to decision-making in treatment of mouth breathing individuals, the orthodontists in Passo Fundo/RS agree that there is need for speech therapy. The full vision of the individual in a multidisciplinary team is of fundamental importance in the treatment of patients with mouth breathing syndrome.

Keywords: Mouth breathing. Orthodontics. Speech therapy.

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Editor's abstract

Mouth breathing is characterized by a deviation of nasal breathing, and this is a disorder that affects the growth and development of the whole orofacial system. When it is constant, mouth breathing triggers a chain of events that affect the child's development, and even the adults in their usual activities. Nowadays, it is known that the treatment of chronic mouth breathing requires an interdisciplinary approach, since it is impossible for only one professional to recover functional, pathological, structural, postural and emotional needs of patients with this syndrome.

Thus, the proposal of the authors of the present work was to verify the clinical decision-making by orthodontists from Passo Fundo/RS (Brazil) in the interrelationship with speech therapy in mouth breathers. The sample included 22 orthodontists, working in the city of Passo Fundo, according to the Regional Dental Council. The survey instrument applied to Orthodontists was a questionnaire with objective and subjective questions, in the first part it consisted of demographic data (gender, age, years after graduation, college, specialization in Orthodontics and professional performance). The second part consisted of questions concerning the

interrelationship orthodontics/speech therapy, ie, the data referring to the criteria regarding clinical decision-making of orthodontists. The data collected in the sample were submitted to statistical tests using the statistical software - SPSS 15.0. The results showed that all professionals consider necessary the interrelationship between orthodontics and speech therapy, but there was disagreement as to situations where there is the possibility of working together, whereas 54.5% rely on the inter-relationship to develop aspects related to language, orofacial motricity and habits.

In cases of interdisciplinary treatment, the results were considered satisfactory by 73.7% of professionals, although they consider that only 6-20% of their patients cooperate with the treatment. Thus, the authors conclude with this work that in relation to clinical decision-making on treatment of individuals with mouth breathing, all the respondent orthodontists of Passo Fundo-RS agreed that there is a need of relationship with speech therapists; the orthodontists in the city make the decision to treat their patients referring them to speech therapist and follow their treatment, but most of them feel the patients are not comfortable to perform the speech therapy.

Influence of Ortho Primer Morelli adhesion booster on orthodontic brackets shear bond strength

Sabrina de Mendonça Invernici¹, Ivan Toshio Maruo², Elisa Souza Camargo³, Thais Miyuki Hirata¹, Hiroshi Maruo⁴, Odilon Guariza Filho³, Orlando Tanaka⁴

Objective: This work aimed at assessing the bond strength (AS), the site of the flaw and the relation between them and Ortho Primer Morelli® (OPM) adhesion optimizer.

Methods: Sixty test specimens, made out of bovine permanent lower incisors, were divided into three groups: TXT Primer (control), in which a conventional adhesive system was applied (primer and paste); OPM, in which TXT primer was replaced by OPM; and TXT without Primer, in which only TXT paste was used. A shear force was applied at a speed of 0,5 mm/min. Failure site was assessed by the Remaining Adhesion Index (RAI).

Results: Kruskal-Wallis demonstrated that OPM (8.54 ± 1.86 MPa) presented a statistically higher AS ($p < 0.05$) IF compared to TXT Primer (6.83 ± 2.05 MPa). There was no statistically significant difference ($p > 0.05$) between TXT with or without Primer (6.42 ± 2.12 MPa). Regarding the RAI, the K test demonstrated that TXT Primer and OPM (prevailing scores 2 and 3) showed higher values ($p < 0.05$) IF compared to TXT without Primer (prevailing scores 0 and 1). Spearman demonstrated that there was no correlation between AS and RAI ($p > 0.05$).

Conclusion: OPM increases AS and presents the same bond failure location if compared to a conventional adhesive system; the use of the TXT adhesive system paste only was shown to have the same AS if compared to conventional systems, except it does not allow to predict the adhesive failure site; there is no correlation between AS and bond failure location, regardless of the use of any adhesion optimizer.

Keywords: Primer. Adhesion. Shear adhesive strength.

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INTRODUCTION

The bonding of orthodontic brackets was first attempted by Newman¹⁶ and has become a clinically accepted technique since 1970, when new dental bonding agents started to be developed in pursue of accomplishing higher adhesion to either enamel or dentin. Bonded brackets have replaced teeth banding, and this technique is quite superior in maintaining gingival and dental health, as well as better esthetics.¹⁰

Adhesion procedures are based on enamel surface changes created by acid etching, developed by Buonocore.³ Obtaining an efficient adhesion between orthodontic brackets and the bonding surface of teeth, by means of a good bonding system, is of great benefit to orthodontic treatments. The efficiency offered by bonding systems is paramount to the adhesion of orthodontic pieces, since loose brackets during treatment mean lost money for both patients and dentists.²¹

Many different products have been launched on the market as an attempt to increase bonding agent's adhesive strength, and studies about bonding optimizers have become quite common in the literature.¹⁷ According to Reynolds,¹⁹ bonding agents applied between acid etching and resin increase enamel adhesion. Nevertheless, other authors^{4,5,18} did not observe any increase in the adhesive strength when comparing conventional and primer based systems.

It can therefore be observed that not all published pieces of research take for granted the real potential of bonding optimizers in order to increase adhesive strength. This lingering concern has fostered the study about adhesive strength of a material recently launched in the market by Morelli®, which is presented as a light cured acrylic based adhesion promoting agent, with hydrophilic properties, pointed out as an adjunct to bonding both metallic and ceramic brackets.

MATERIAL AND METHODS

Ninety bovine lower permanent incisors without enamel alterations were obtained. After soft tissue removal, crowns were separated from the roots and kept in 0.1% thymol water solution, under room temperature (approximately 37° C).

Teeth segments (5 x 5 mm) were severed from the flattest buccal surfaces with a carborundum disc and cooling water spray. A clay sphere was manufactured

and was pressed between two glass slabs, with a 1 mm thick stainless steel clamp (Figs 1B – E) in order to obtain a standardized thickness. Each tooth segment was pressed against the glass slab and fixed with clay in order to have the enamel flattest surface in contact with the slab (Figs 1F, G). An aluminium ring (24 mm diameter x 20 mm height) was placed over the glass slab, centralizing the tooth segment inside it (Fig 1H). Transparent self-cured acrylic resin was manipulated and poured inside the aluminium ring (24 mm diameter x 20 mm height), which had its inner surface insulated with petroleum jelly (Figs 1I, J). After acrylic resin full set, test specimens were removed from the rings and rinsed under running water (Figs 1L – O).

Bracket bonding

Once a good prophylaxis was performed with pumice powder and water, applied with a rubber cup, during 10 seconds, over all exposed enamel surfaces, teeth were washed with water spray for 10 sec and blown dry for another 10 seconds at 5 cm distance, using a moisture and grease free air syringe. Rubber cups were replaced every 5 test samples.

After that, enamel surfaces were etched with 37% phosphoric acid for 15 sec, rinsed for 15 seconds and blown dry for another 15 sec with the air syringe at a 5 cm distance.

Sample division into three groups proceeded, each one containing thirty test specimens, according to specifications below:

- » Transbond XT® Primer Group (control group) – A layer of Transbond XT® (3M Unitek) primer was applied over enamel etched surface, followed by a two seconds light air blow, as advised by the manufacturer.

- » Ortho Primer Morelli® Group – Ortho Primer Morelli® was used in this group according to manufacturer's instructions, that is, a thin layer of primer applied on both bracket and etched enamel, replacing the primer from Transbond XT® composite.

- » Transbond XT® without Primer Group – No primer was applied in this group.

In all three groups, a good layer of Transbond XT® (3M Unitek) was spread on the base of the orthodontic piece (lower central incisor bracket with 12 mm² of base dimension – Morelli ref: 10.30.209) and bonded to the teeth. In order to standardize the thickness of the adhesion material, brackets underwent 400

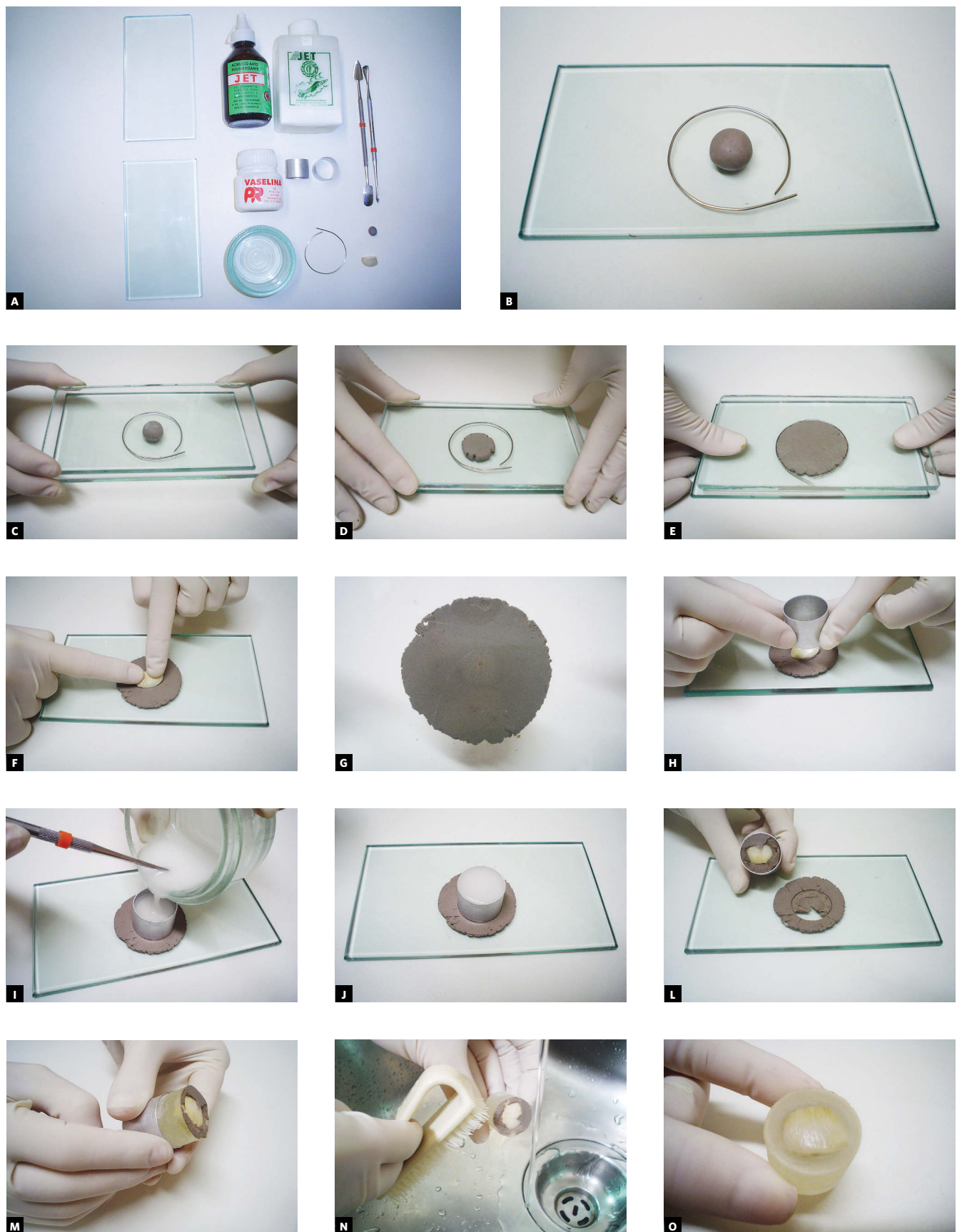


Figure 1 - Test specimens manufacturing.

grams strength on a dynamometer (Morelli – ref. 75.02.006) (Fig 2). After removing the excesses with an exploratory probe, the material was light cured for 40 seconds (10 seconds for each side of the bracket) at a distance of 2 mm, using Optilux (3M Unitek) as the light source and 630 mW/cm² of power.

After light curing, sample specimens were stored in distilled water at room temperature for two hours.

Bracket removal

In order to assess the adhesive strength (AS), test specimens were positioned and fixed by a stainless steel and threaded bolt device in such a way the brackets slots would be parallel to the shear force thus minimizing the “wing deformation” factor.

Shear test for bracket removal was performed 32 hours after bonding in a EMIC DL500® Universal Assay Machine (Equipamento de Ensaio Ltda., São José dos Pinhais, Brazil) (Fig 3), in the Laboratory of Characterization and Material Assays of the Mechanical Engineering Course, at Pontifical University of Paraná Technological Park. The speed was 0,5 mm/min, with a load cell of 50 kN and a computer unit connected to the machine recording the result of the breaking strength (MPa) of each test, considering the basal area of the brackets.

Once removed, brackets and teeth were examined under 10X magnification in a stereoscopic microscope in order to record the remaining adhesive index (RAI), ranked in a 0 to 3 scale (Årtun and Bergland).¹ Score 0 indicates the absence of material adhered to the tooth; 1 indicates that less than half of the material is still attached to the tooth; 2 indicates that more than half of the material is adhered to the tooth and 3 indicates that all material is still adhered to the tooth, including the bracket mesh print. Scores 0 and 1 indicate an adhesive failure in enamel/adhesive interface, while scores 2 and 3 represent failures in bracket/adhesive interface.

All data were logged and submitted to statistical analysis.

RESULTS

Adhesive strength (AS)

Descriptive statistics of the AS variable is presented in Table 1. Considering this variable, groups were assessed for the normality by a Kolmogorov-Smirnov



Figure 2 - Bracket being placed under the dynamometer and excesses removed with the probe.

test and for the variance homogeneity by a Lavene test. Only Transbond XT Primer Group did not present a normal distribution.

Therefore, the comparison of AS average values between groups was done through a non parametric Kruskal-Wallis H test, which demonstrated that the AS variable average values were higher for the Ortho Primer Morelli® group, presenting a statistic difference ($p < 0.01$) when compared to Transbond XT® Primer and Transbond XT® without Primer, although Transbond XT® Primer and Transbond XT® without Primer did not present statistic difference between one another ($p > 0.05$).

Remaining adhesive index (RAI)

Figure 4 presents the RAI frequency distribution amongst the assessed groups. The group with the higher average RAI score was Transbond XT® Primer Group whilst Transbond XT® without Primer was the one with the lower average score. Groups Ortho Primer Morelli® and Transbond XT® without Primer presented a heterogeneous distribution since Pearson V.C. (%) variation coefficient exceeded 30%.

Kruskal-Wallis non parametric test revealed that RAI average scores of Transbond XT® without Primer Group presented statistic difference ($p < 0.01$) when compared to the other groups, although Ortho Primer Morelli® e Transbond XT® Primer Groups did not present statistic difference between themselves ($p > 0.05$).

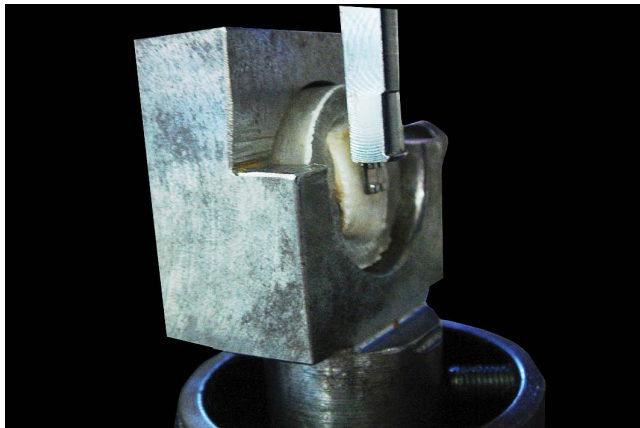


Figure 3 - Shear test in an EMIC DL500® testing machine.

Correlation between AS and RAI

Spearman correlation coefficient calculation between AS and RAI variables presented a value equal to 0.18, not statistically significant ($p > 0.05$), pointing to an absence of correlation between variables AS and RAI.

DISCUSSION

Bond Enhancing Primers were first launched in the market as an attempt to brackets adhesive strength, which would get loose very often when submitted to masticatory loading, hindering orthodontic treatment results for both patients and clinicians. From a patient standpoint, loose brackets mean longer visits and more discomfort at the dental Office in order to get them fixed, possibly increasing total treatment time. For orthodontists, on the other hand, it means longer clinical sessions dedicated to the office, higher material costs, let alone the delay in concluding the treatment.

Ortho Primer Morelli® studied here is used as a surrogate to primers from the original systems selected for the bonding, and aims at increasing brackets adhesive strength. For this sample, Transbond XT® adhesive system was chosen as the control since it is universally accepted and considered as excellent quality.²

For the *in vitro* assessment performed in this study, bovine teeth were used given the challenge of gathering extracted human teeth. This is justifiable,

Table 1 - Descriptive Statistics of adhesive strength according to groups.

Groups	n	Average	Median	Standard Deviation	V.C. (%)
Transbond XT primer	30	6.83	6.37	2.05	29.96
Ortho Primer Morelli	30	8.54	8.57	1.86	21.74
Transbond XT without primer	30	6.42	6.43	2.12	33.03

V.C. = Variation Coefficient

Source: Research data.

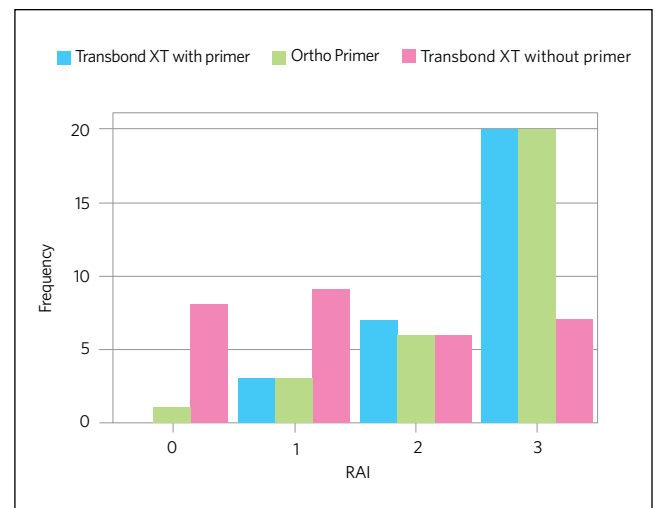


Figure 4 - Remaining adhesive index frequency distribution by groups (Source: PUC-PR, 2008).

since other authors^{15,17} have compared the adhesive strength of composites and cements bonded to both types of enamel and observed no statistic significant difference, although values were slightly lower for bovine teeth.

With regards to test specimens manufacturing, enamel surfaces over which the bonding occurred were not sanded. According to Ritter et al,²⁰ tests performed in both sanded and non-sanded enamel surfaces did not present statistically significant differences in the adhesive strength values. Although the sanding is responsible for a flatter bonding surface, not sanding the samples was justifiable for the present study aims at assessing the physical

properties of primers on enamel. Considering the variability of enamel thickness,¹¹ were teeth surfaces to be sanded, there would be a great risk of reaching the dentin, with considerably different physical and chemical properties from enamel ones.

In this way, result differences observed in many research works may be due to the different work methodologies, or to the different type of teeth used (bovine or human);¹⁵ teeth storage after extraction; if thermo cycling is performed or not; sample specimens manufacturing procedures; treatments applied to enamel;⁴ time and type of acid etchant;²² differences between materials used in the work such as primers, adhesive systems and brackets;⁸ mechanical assay machinery for testing and load cell applied to the bracket;^{12,18} after test storage material and period, amongst others. All these variables make it difficult to compare research's absolute results with one another and, for that reason, what should be taken in to account when comparing such values is the statistic significance of the adhesive strengths.

During result assessment, Ortho Primer Morelli® Group was proven to have a higher adhesive strength value, corresponding to 8.54 ± 1.86 MPa ($p < 0.05$), when compared to the other two groups tested, which presented 6.83 ± 2.05 MPa (Transbond XT® Primer Group) and 6.42 ± 2.12 MPa (Transbond XT® without Primer Group). This adhesive strength increase is even higher than the upper limit recommended by Reynolds,¹⁹ in 1975, who suggests that adhesive strengths varying between 6.0 and 8.0 MPa would suffice.

These results mean that the adhesive strength promoted by Ortho Primer Morelli® is higher than the conventional system ones, just as described by Harari et al,⁹ in 2000, when they tested High-Q-Bond adhesion promoting primer, comparing it to the Right-On conventional adhesive system. The authors obtained a higher average adhesive strength for High-Q-Bond, for brackets bonded on both enamel 9.90 ± 2.09 MPa and amalgam 6.89 ± 1.82 MPa, against 8.29 ± 3.18 MPa and 5.48 ± 1.77 MPa, respectively, obtained with Right-On.

In another work from 2002, Harari, Gillis and Redlich¹⁰ observed that groups where an bond enhancing primer was used presented a satisfactory adhesive strength for the orthodontic practice, even though no

acid etching was performed, using Reynolds¹⁹ parameters, as an alternative to decrease the number of steps during the orthodontic bracket bonding procedure.

Grandhi, Combe and Speidel,⁸ in 2001, have also obtained higher results during shear tests for the bond enhancing primer when tested Transbond MIP primer with Transbond XT composite resin, the same way did Mavropoulos et al,¹⁴ in 2003, when tested Transbond MIP primer, comparing it to a chemically cured Unite composite resin. Vicente et al,²⁵ in 2006, also obtained statistically significant higher values in adhesive strength tests for the groups where Enhance-LC adhesion promoting primer was used, especially when it was used together with the Light-Bond system as recommended by the manufacturer.

Grandhi, Combe and Speidel⁸ observed satisfactory adhesive strength results with Transbond XT composite resin associated to a moisture tolerant primer, in a moist environment. Nevertheless, the authors do not recommend the use of the same primer together with the Concise chemically cured composite resin since the hydrophobic nature of the composite repels the MIP primer. They suggest its should only be used with light cured composite resins.

Vicente et al²⁴ in their work of assessment of the adhesive strength of the Enhance-LC bonding promotion agent, have found values that are way beyond those recommended for Orthodontic purposes, according to Reynolds parameters. Authors have advised it should only be used in non-compliant patients to the orthodontic therapy or in places where moist control is very difficult, which need a higher bracket adhesive strength. Such statements end up encouraging further research with Ortho Primer Morelli® in wet environments.

Wegner, Deacon and Harradine,²⁶ in 2008, compared the Orthosolo bond enhancing agent to the conventional Transbond XT system and found no statistic difference in the adhesive strength assessment between conventional systems and bond enhancing agents, pretty much as Coreil et al,⁵ Chung et al⁴ and Owens and Miller¹⁸ in their respective works. Coreil et al,⁵ nonetheless, have performed the bonding in human teeth with sanded surfaces. Chung et al⁴ obtained an increase in the adhesive strength after the tests were done using primer

only for the re-bonded brackets group. For the new brackets group, there was no statistic difference between the two systems.

Results reporting a decrease in the adhesive strength in groups where a bond enhancing primer was used were found by Littlewood et al,¹² diverging from the results obtained in the present study. According to the afore mentioned authors, these results may be due to the fact that primers are hydrophilic and the tests were performed on dry conditions, under the justifying argument that standardization is hard to be achieved in wet test environments.

Littlewood, Mitchell and Greenwood,¹³ compared a traditional primer and a hydrophilic orthodontic primer and observed a decrease in the adhesive strength for bracket bonding when compared to a conventional system primer, used with Transbond XT composite resin. They have recommended that hydrophilic primers should only be used in places where the moisture control is hard to obtain.

Since all works quoted, as well as the present study, were performed *in vitro*, it is advisable that further studies should check on the clinical feasibility of Ortho Primer Morelli®, such as Mavropoulos et al¹⁴ did in a research preformed using Transbond MIP primer.

Flaw sites are as important as the adhesive strength of a given material. When using primers, the goal is to increase the adhesive strength to a limited extent, since far too high of an adhesive strength may cause damages to enamel structures during bracket removal.²⁴ One of the methods used in order to assess material behaviour when brackets come loose is the Remaining Adhesive Index (RAI), created by Årtun and Bergland,¹ in 1984, and applied to the present work.

During the RAI analysis performed in the present work, both the system which used the conventional system primer and Ortho Primer Morelli® presented a prevalence in the fracture site taking place between the bracket and the bonding agent (adhesive), with 90% and 87% of test specimens presenting scores 2 and 3, respectively. There was no statistically significant difference of RAI between groups. This adhesive flaw between composite and bracket was also found in other studies.^{4,5,10,12}

Results differing from the ones presented here were described by Harari et al,⁹ Owens and Miller¹⁸

and Mavropoulos et al,¹⁴ who have verified a lower RAI in the groups where bond enhancing primers were applied, which means that the flaw took place in the enamel/bond interface. Vicente et al,^{24,25} in their works where Enhance-LC primer was tested, no statistically significant difference was observed between the remaining composite indexes between the control and the groups where the bond enhancing agent was used.

For many authors^{4,5,9,10,12,14,18} the adhesive failure between the adhesive and the bracket is a drawback, for during the removal of the remaining adhesive there could be enamel wearing. For this reason, the best case scenario, according to the authors, would have the remaining adhesive left at the base of the bracket instead of at the enamel surface.

Nevertheless, according to Shojaei et al,²³ if the flaw happens in the enamel/adhesive interface, the likelihood of a tooth fracture event is higher, and the ideal would be flaws taking place between the bonding agent and the bracket, with the remaining adhesive being carefully removed by the dentist. In spite of that, Harari et al,⁹ Owens and Miller¹⁸ and Mavropoulos et al¹⁴ consider the enamel/adhesive failure as a positive issue, once after bracket removal the enamel is adhesive free and saves further interventions with instruments that could damage the enamel structure.

The present work used a group where the adhesive paste was directly applied on the etched enamel surface without any primer: Transbond XT® without Primer Group. None of the works found in the literature review did this comparison. With regards to the adhesive strength, this group obtained values ($p > 0.05$) that are statistically equivalent to the group that used the conventional primer (Transbond XT® Primer Group).

When it comes to the adhesive failure, Transbond XT® without Primer Group presented 57% of flaws in the enamel/adhesive interface (scores 0 and 1) and 43% in the adhesive/bracket interface (scores 2 and 3), presenting significant statistic differences ($p < 0.05$) vis a vis to the groups that used primers (Transbond XT® Primer Group and Ortho Primer® Group) (Fig 4).

It is suggested that the use of primers within the conventional system is not recommended for an increase in the adhesive strength but rather to a better

predictability of the failure location taking place in the adhesive/bracket interface.

This study revealed no correlation between the adhesive strength and the site of the adhesive failure, in other works, an increased adhesive strength does not necessarily imply a higher bonding between enamel and adhesive.

The use of bond enhancing agents in orthodontics as an attempt to achieve better results in terms of adhesive strength in bonding brackets has become increasingly frequent in orthodontic practice and has presented favorable outcomes^{8,9,10,25}. Another favorable issue with regards to the use of these primers is the fact that they cause no harm to the enamel during bracket removal^{4,5,10,12}.

In the present paper, Ortho Primer Morelli® has proven to be quite a promising material. From the results gathered in this *in vitro* study, it is suggested that further research with Ortho Primer Morelli® should be performed in an *in vivo* setting.

CONCLUSION

With the present results, we can conclude that:

- » Ortho Primer Morelli® bond enhancing primer increases adhesive strength when compared to the conventional adhesive system.
- » Ortho Primer Morelli® bond enhancing primer presents the same failure site to the conventional adhesive system, that is the adhesive/bracket interface.
- » The single use of Transbond XT® adhesive system paste presents the same adhesive strength when compared to the conventional adhesive system.
- » The single use of Transbond XT® adhesive system paste does not allow one to foresee the site of the adhesive failure.
- » There is no correlation whatsoever between adhesive strength and the adhesive failure location, regardless of the use of any bond enhancing agent.

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Assessment of the mandibular symphysis of Caucasian Brazilian adults with well-balanced faces and normal occlusion: The influence of gender and facial type

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Objective: This study aimed to establish cephalometric reference values for mandibular symphysis in adults. Dentoalveolar, skeletal and soft tissue variables were measured considering the influence of gender and facial type.

Methods: The sample consisted of sixty cephalometric radiographs of white Brazilian adult patients, with a mean age of 27 years and 6 months, who had not undergone orthodontic treatment and who presented well-balanced faces and normal occlusion. The sample was standardized according to gender (30 males and 30 females) and facial type (20 were dolichofacial, 20 mesofacial and 20 brachyfacial).

Results: The results showed that male and female symphyses are similar, except for symphyseal height, which was greater in males. In terms of facial type, the dolichofacial group presented narrower symphysis in dentoalveolar and basal areas, with a more accentuated lingual dentoalveolar inclination.

Conclusion: The brachyfacial group showed broader symphysis in the dentoalveolar and basal areas and a greater buccal dentoalveolar inclination. The projection of the chin was 6.67 mm below the subnasal vertical line and there was no significant difference between the genders or facial types.

Keywords: Mandibular symphysis. Gender. Facial type. Facial balance.

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

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INTRODUCTION

Mandibular symphysis is an anatomical structure of the mandible in which the lower incisors are found including the anterior portion of the chin. Mandibular symphysis contributes to the composition and balance of facial harmony^{2,15,25} and must be considered when deciding on orthodontic treatment in borderline cases.^{12,20,30}

Mandibular symphysis is morphologically divided into two regions, the dentoalveolar and basal symphyses.²² The dentoalveolar symphysis includes the alveolar process and lower incisors. The long axis of the lower incisors cephalometrically matches the long axis of the alveolar process²² and its inclination is influenced by facial type.^{16,29} This classical concept dates from the Tweed era and defines the lingual inclination of the alveolar long axis (IMPA) in subjects with a high mandibular plane (FMA), while in subjects with low mandibular planes, the long axis is more buccally tipped.²⁹ According to this view, the positioning error of the lower incisors could compromise the stability of orthodontic results and facial esthetics.²⁹

Alveolar bone thickness varies according to location and facial type.¹² Generally, there is a greater bone thickness at the apex than in the cervical region, and towards the lingual surface when compared to the labial surface.¹² This explains the higher prevalence of bone dehiscence and fenestration on the buccal side, and gives rise to periodontal concern about the anterior orthodontic movement of the lower incisors.⁸

However, studies related to buccal projection^{3,4,9,10,19,28,30} of lower incisors present conflicting results, probably due to methodological differences and limitations, and the multifactorial etiology of periodontal recession.³¹ However, thin buccal bone coverage of the root^{10,12,28} associated to excessive buccal movement³¹ and insufficient thickness of the marginal gingiva have been shown^{19,31} to be significant variables in the development of non-inflammatory gingival recession.

In terms of cortical bone, the lingual side is thicker than the buccal, and due to the inclination of the lower incisors, there is a closer approximation of the root apex to the lingual cortical. This apex relationship is particularly evidenced in subjects

with vertical growth tendency¹² and Class III malocclusion.^{12,22} since the alveolar bone is very narrow in this region. Bone in the referred apical region is assumed as non-remodelable anatomical limit and restricts the orthodontic retraction movement, because it can perforate the lingual cortical.^{12,20,24}

The basal symphysis is part of the main body of the mandibular symphysis with more apical location, setting the hard menton outline. The menton is considered to be a recent phylogenetic acquisition (just over 10,000 years ago), exclusive to *Homo sapiens*. The morphological variation of the menton has a strong genetic basis and its occurrence may have emerged casually¹⁴ and, did not add any biomechanical advantages for mastication.

The long axis of the basal symphysis differs cephalometrically from that of the alveolar symphysis.²² Tooth movement of the lower incisors cannot influence the shape or position of the basal symphysis. The relationship between the height and width of the mandibular symphysis is one of Björk's five criteria for establishing the mandibular rotation pattern during growth.^{1,5,6,27} For long and narrow symphyses, the tendency of mandibular rotation during growth is predominantly vertical; when short and wide, it is predominantly horizontal.⁵ In the vertical pattern, a mandibular symphysis with a long axis and greater lingual inclination has also been observed.^{12,16}

The morphology of the mandibular symphysis is also influenced by the sagittal growth pattern.^{12,16,22} In Class III malocclusion, a higher,²² narrower¹² symphysis with greater anterior projection¹⁶ and evident lingual inclination of the long axis has been identified.^{16,22}

In addition, the height and projection of the basal symphysis influence the position of the adjacent soft tissue and are significant in terms of aesthetic and facial harmony.^{2,15,25} Menton deformities can be treated satisfactorily using basilar genioplasty. For this procedure, it is necessary to establish normative values for height and anterior projection, that are both influenced by ethnicity and sexual dimorphism. These values are usually higher in males.²

Despite its relevance, few studies have focused on mandibular symphysis^{17,26} and its standard cephalometric values. Some studies lack for uniformity in the sample regarding ethnicity, facial pattern and malocclusion. Hence, the objective of this study was

to describe the morphology of the mandibular symphysis in a sample of Brazilian adults with well-balanced faces and normal occlusion, individualized in terms of gender and facial type variables.

SUBJECTS AND METHODS

The research project was submitted to the Research Ethics Committee of *Universidade Federal de Uberlândia* and approved under the protocol number 247/07.

Sample selection

The total sample, composed of 60 subjects with well-balanced faces, equally divided between the genders, was prospectively selected from students of the Federal University of Goiás Dental School and complemented with subjects retrospectively selected from patients with minimum morphological occlusion deviations from the researchers' private clinics. The mean age of participants was 27 years and 6 months. The sample was also evenly distributed between the possible vertical variations in terms of facial type (dolichofacial, mesofacial and brachyfacial) (Table 1).

The following inclusion criteria had to be fulfilled by all participants: 1) be Brazilian; 2) Caucasian; 3) males over 18 and females over 16; 4) ANB between 0° and 4°; 5) well-balanced face; 6) apparent facial symmetry (clinically determined); 7) normal occlusion with Class I canine and molar relationship, overjet and overbite up to 3 mm and crowding up to 4 mm; 8) presence of all teeth, except third molars; 9) no serious medical condition; 10) no history of facial or dental trauma; 11) no previous orthodontic or prosthetic treatment, facial plastic surgery or orthognathic surgery.

In this study, all the subjects showed a well-balanced face according to Capelloza's Pattern I description.^{7,23} There were no skeletal discrepancies in sagittal

or vertical directions, and the profile was orthognathic, in other words, with gentle facial convexity, lips sealed when resting, the proportion of the facial thirds and the upper lip height were equal to half the height of the lower lip. In order to define the facial type, concordance between the subjective facial analysis and the angle of the mandibular plane (SN.GoGn) were used as criteria. Subjects were classified as mesofacial when SN.GoGn was between 30° and 34°, brachyfacial when less than 30° and dolichofacial when greater than 34°. For profile evaluation, the menton-neck line (length and angle) was used. Subjects were characterized as brachyfacial when the line was elongated and the angle more open. For mesofacial subjects, the line was proportional and the angle close to 90°. For dolichofacial subjects, the line was shortened and the angle reduced. For the frontal evaluation, the referential used was the width between gonion landmarks. This reference was comparatively larger for the brachyfacial type, balanced for the mesofacial type and narrow for the dolichofacial type. Cases in which the facial analysis was not compatible with the SN.GoGn angle were excluded from the sample (Fig 1).

Cephalometric method

After the radiographs were taken, the cephalogram was performed by a single calibrated examiner. Ultraphan paper, a 0.5 mm propelling pencil, soft white eraser, ruler, protractor, square (Desotec) and lightbox were used. The tracings were performed using predefined points, lines and planes in a dark room using black cardboard to protect the edges of the radiographic film. The values obtained were rounded off to 0.5 or the nearest whole number when decimal values were found. Radiographs were excluded when it was impossible to identify anatomical design.

The cephalometric landmarks used were (Fig 2):

- » Or (orbital): The lowest edge of the infraorbital margin.
- » Po (Porion): Highest edge of the external auditory canal.
- » Gn (gnathion): Lowest and most anterior edge of the symphysis.
- » Me (menton): The lowest edge of the menton symphysis outline.
- » Go (gonion): The lowest and most posterior point of the gonial angle.

Table 1 - Sample distribution according to gender and facial type.

	Brachyfacial	Mesofacial	Dolichofacial	Total
Male	10	10	10	30
Female	10	10	10	30
Total	20	20	20	60



Figure 1 - Extraoral photographs (front and profile) and lateral radiographs with corresponding SN.GoGn values, representative of the female sample. Facial balance was classified into three facial types: **A)** Brachyfacial, **B)** mesofacial and **C)** dolichofacial.

- » Pog (pogonion): Most prominent edge in the symphysis.
- » Pog' (soft pogonion): Most prominent edge of menton soft tissue.
- » Pog'' (lingual pogonion): Suggested by Nojima et al²², represents the most posterior point located in the external lingual cortical of the mandibular symphysis.
- » Sn (subnasal): Point located at the junction between the upper lip and the base of the nose.
- » IiI: The uppermost point of the lower incisor incisal edge.
- » AIi: Lowest point located at the root apex of the lower incisor.
- » Sf: Midpoint between the outer lingual and outer buccal corticals in the IiAIperp line, suggested by the authors of this study.
- » Mi: Point on the mesiobuccal cusp tip of the lower first molar.

The lines and planes used were (Fig 3):

- » OrPo: Frankfurt horizontal plane.
- » GoMe: Mandibular plane.
- » IiAIi: Long axis of the lower incisors also representing the long axis of the alveolar symphysis.
- » IiAIperp line: Tangent to the apex of the lower incisors perpendicular to their long axis as defined by the authors of this study.
- » Sn perp OrPo: Line passing through the Sn, perpendicular to the Frankfurt plane.
- » SfMe: Long axis of the basal symphysis.
- » IiMi: Mandibular occlusal plane (MOP), suggested by Arnett et al.²

The angular measurements used were (Fig 3):

- » SN. GoGn: Mandibular plane inclination in relation to the base of the skull.
- » IMPA (GoMe.IiAIi): Lower incisor inclination in relation to the mandibular plane, also representing the alveolar symphysis inclination.
- » FMIA (OrPo.IiAIi): Lower incisor inclination in relation to Frankfurt plane.
- » IiAIi.MOP: Lower incisor inclination in relation to the mandibular occlusal plane.
- » SfMe. GoMe: Inclination of the basal symphysis in relation to the mandibular plane.
- » SfMe. OrPo: Inclination of the basal symphysis in relation to the Frankfurt plane.

The linear measurements evaluated were (Fig 3):

- » IiAIiMe: Distance from the projection of the long axis of the lower incisors on the mandibular plane to the Me point.
- » BBD: Buccal bone distance, comprising the thickness of the buccal alveolar bone at the apex of the lower incisors, measured from the AIi point to the external buccal cortical point, using the path of the IiAIperp line.
- » LBD: Lingual bone distance, comprising the thickness of the lingual alveolar bone at the apex of the lower incisors, measured from the AIi point to the external lingual cortical point, using the path of the IiAIperp line.
- » PogPog'': Distance between the pogonian and the lingual pogonian points representing the thickness of the basal symphysis, suggested by Nojima et al.²²
- » IiMe: Height of the long axis of the mandibular symphysis.
- » Pog'Sn (perpOrPo): Distance from the menton soft tissue to the subnasal line perpendicular to the Frankfurt plane.

Systematic error

In order to evaluate the systematic error, 20 randomly selected radiographs used in this study, were remeasured after 30 days. To determine intra-examiner error, the paired t test was applied. Random error was calculated using Dahlberg's test¹³ when error values greater than 1.5° or 1.0 mm were found. As noted in Table 2, systematic error was statistically significant for SN.GoGn and SfMe.OrPo, but with a slight average difference (0.67° and 0.62°, respectively), irrelevant from the clinical point of view. The results revealed a random error less than 1.5° and 1.0 mm, indicating the reliability of the data.

Statistical Analysis

Data normality of distribution was verified by the Kolmogorov-Smirnov test. A comparison of cephalometric measurements according to gender and facial type was performed using Student's t test for independent samples and analysis of variance (ANOVA), respectively. When the ANOVA indicated a statistically significant difference, the Tukey test for multiple comparisons was applied.

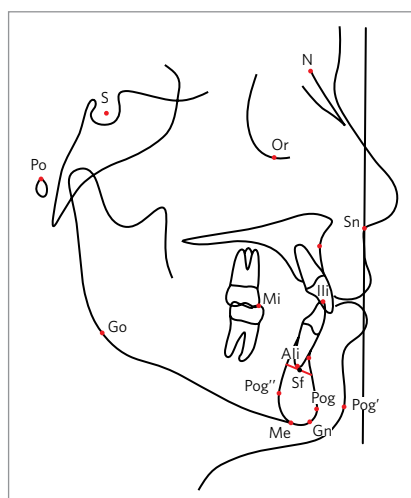


Figure 2 - Cephalometric landmarks used, emphasizing the Sf.

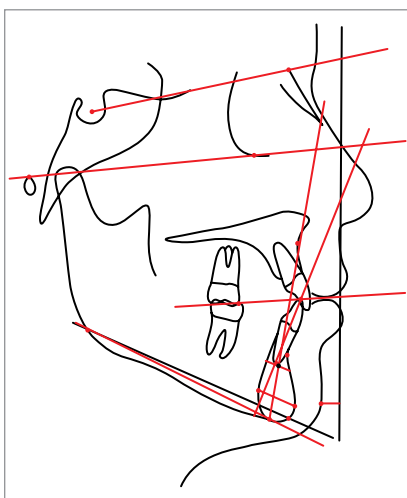


Figure 3 - Lines, planes and cephalometric measurements.

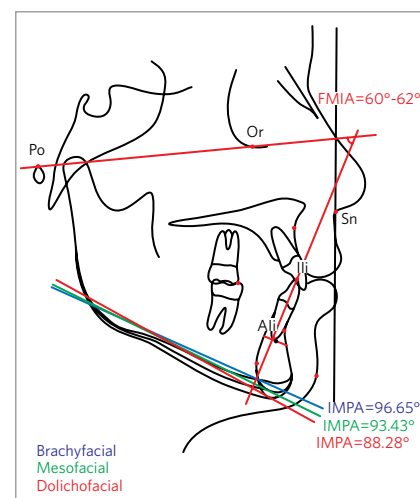


Figure 4 - Variations in dentoalveolar symphysis inclination means (long axis of the lower incisors, measured using IMPA and FMIA) as a variation of the mandibular plane (FMA).

For the statistical treatment of data, the SPSS for Windows (version 16.0) was used, considering a significance level of 5% ($\alpha = 0.05$).

RESULTS

Composition and characteristics of the sample

The sample consisted of subjects ranging from 18 to 38 years for males and 16 to 35 years for females. All subjects presented well-balanced faces, confirmed by subjective facial analysis and cephalometric measurements. The average ANB angle was $2.16 \pm 1.63^\circ$, indicating harmony in the sagittal position of both maxilla and mandible, and the average SN.GoGn was $32.11 \pm 5.46^\circ$, which confirmed facial balance in the vertical position. Classification in terms of facial type was clearly established by SN.GoGn cutoff values (Fig 4).

In this study, the buccolingual inclination of the lower incisors represented the long axis of alveolar symphysis. The cephalometric measurements which contributed to this evaluation were IMPA, FMIA, IiAiIi.POM and IiAiIi.Me. In general, the lower incisors were implanted perpendicular to the mandibular base ($\text{IMPA} = 92.78^\circ$), buccally in relation to the Frankfurt horizontal plane ($\text{FMIA} = 61.13^\circ$) and lower occlusal plane ($\text{IiAiIi.MOP} = 63.10^\circ$) and the projection of the long axis of these teeth is about 9.51 mm after the Me point (Table 3).

The amount of buccal and lingual bone at the apex of the lower incisor was measured by BBD

and LBD widths, respectively. In this sample, the amount of buccal bone ($\text{BBD} = 5.12 \text{ mm}$) was thicker than the amount found for lingual bone ($\text{LBD} = 3.55 \text{ mm}$) (Table 3). The long axis of the basal and alveolar symphysis was not aligned. The basal symphysis was inclined 22° lingually in terms of the dentoalveolar symphysis in relation to both the mandibular and Frankfurt planes ($\text{SfMe.GoMe} = 70.33 \pm 5.44^\circ$ and $\text{SfMe.OrPo} = 83.13 \pm 6.50^\circ$). The width of the basal symphysis baseline was 15.61 mm (PogPog''), considered almost twice ($\text{BBD LBD} = 8.67 \text{ mm}$) that of the dentoalveolar symphysis at the apex of the lower incisors. Symphysis height (IiIiMe) was $44.78 \pm 3.79 \text{ mm}$ and in terms of soft tissue, the projection of the Pog' remained about 6.7 mm below the vertical subnasal line [$\text{Pog'-Sn(perp OrPo)}$] (Table 3).

Gender

Regarding gender, the results showed no statistically significant difference for most cephalometric measurements. Hence, as a general rule, both male and female mandibular symphysis have a similar morphology, except for a slight inclination of the basal symphysis (SfMe.PoOr) and height (IiIiMe).

The basal symphysis inclination in relation to the Frankfurt plane (SfMe.PoOr), was 84.97° for males and 81.28° for females, and this difference was statistically significant at 5% level. However, caution

Table 2 - Systematic error values (paired t test) and random error (Dahlberg).

	First measurement		Second measurement		t	p	Random error
	Mean	s.d.	Mean	s.d.			
SN.GoGn (degrees)	32.65	5.61	33.32	5.42	-3.857	0.001*	0.72
IMPA (degrees)	90.58	5.47	90.5	5.42	0.164	0.871 (ns)	1.41
FMIA (degrees)	62.5	4.96	62.37	4.86	0.253	0.803 (ns)	1.42
IliAli.MOP (degrees)	64.67	5.17	64.95	5.83	-0.456	0.654 (ns)	1.47
IliAliMe (mm)	-7.63	5.11	-6.78	6.29	-0.430	0.672 (ns)	1.01
BBD (mm)	6.00	2.22	6.15	2.14	-0.653	0.522 (ns)	0.72
LBD (mm)	3.53	0.95	3.60	0.88	-0.314	0.757 (ns)	0.74
PogPog" (mm)	16.5	1.97	16.47	1.84	0.165	0.871 (ns)	0.47
SfMe.GoMe (degrees)	71.08	5.16	71.3	4.71	-0.920	0.369 (ns)	0.77
SfMe.OrPo (degrees)	82.25	6.72	81.63	6.43	2.490	0.022*	0.89
IliMe (mm)	45.3	4.19	45.28	4.41	0.165	0.871 (ns)	0.47
PogSn(perpOrPo) (mm)	-6.58	3.74	-6.15	3.71	-1.428	0.169 (ns)	0.87

Table 3 - Cephalometric characteristics of the total sample.

Variable	Mean	s.d.	Maximum value	Minimum value
SN.GoGn (degrees)	32.11	5.46	42	23
IMPA (degrees)	92.78	6.02	103	79.5
FMIA (degrees)	61.13	5.23	71	46
IliAli.MOP (degrees)	63.10	5.43	75	54
IliAliMe (mm)	-9.51	3.11	-3	-19
BBD (mm)	5.12	1.70	12.5	2
LBD (mm)	3.55	1.07	6	1.5
PogPog" (mm)	15.61	2.13	21.5	11
SfMe.GoMe (degrees)	70.33	5.44	84	51.5
SfMe.OrPo (degrees)	83.13	6.50	96	71
IliMe (mm)	44.78	3.79	55	39
Pog'Sn(perp OrPo) (mm)	-6.66	3.88	1	-14

Table 4 - Cephalometric values of the sample according to gender and facial type.

	Total	Gender			Facial type			
		M	F	p	Brachyfacial	Mesofacial	Dolichofacial	p
SN.GoGn (degrees)	32.10 (44.46)	32.91 (44.43)	31.30 (46.30)	0.255	26.50 (42.12) ^A	31.65 (41.10) ^B	38.17(43.86) ^C	0.000
IMPA (degrees)	92.78 (46.02)	93.63 (45.45)	91.93 (46.52)	0.278	96.65 (44.58) ^A	93.42 (45.00) ^A	88.27 (45.38) ^B	0.000
FMIA (degrees)	61.12 (45.23)	60.07 (44.80)	62.18 (45.51)	0.118	61.37 (44.60)	61.00 (44.68)	61.00 (46.47)	0.967
Ili.MOP (degrees)	63.10 (45.42)	63.31 (45.29)	62.88 (45.64)	0.760	60.67 (44.09) ^A	62.60 (45.29) ^{AB}	66.02 (45.60) ^B	0.005
IliAliMe (mm)	-9.50 (43.10)	-8.83 (42.86)	-10.18 (43.24)	0.093	-10.37 (42.07) ^A	-10.07 (44.17) ^{AB}	-8.07 (42.22) ^B	0.037
BBD (mm)	5.11 (41.70)	5.27 (42.04)	4.97 (41.28)	0.499	5.72 (42.00) ^A	5.35 (41.52) ^{AB}	4.27 (41.20) ^B	0.017
LBD (mm)	3.55 (41.06)	3.57 (41.13)	3.53 (41.02)	0.905	4.22 (40.86) ^A	3.37 (41.15) ^B	3.05 (40.82) ^B	0.001
PogPog" (mm)	15.60 (42.12)	15.30 (42.16)	15.91 (42.08)	0.265	16.07 (41.89) ^A	16.12 (42.25) ^A	14.62(41.96) ^B	0.038
SfMe.GoMe (degrees)	70.33 (45.44)	71.45 (45.98)	69.21 (44.68)	0.113	71.42 (44.37)	70.10 (46.63)	69.47 (45.17)	0.520
SfMe.OrPo (degrees)	83.12 (46.50)	81.28 (46.90)	84.96 (45.60)	0.027	86.95 (44.51) ^A	82.72 (46.28) ^{AB}	79.70 (46.60) ^B	0.001
IliMe (mm)	44.77 (43.79)	42.58 (42.13)	46.97 (43.85)	0.000	43.17 (43.06) ^A	44.45 (43.77) ^{AB}	46.70 (43.79) ^B	0.010
PogSn(perpOrPo) (mm)	-6.65 (43.87)	-6.27 (43.89)	-7.05 (43.89)	0.439	-5.15 (43.28)	-6.90 (43.89)	-7.92 (44.07)	0.071

should be exercised when evaluating this finding, because the systematic error was significant for this measurement (Table 4). Mean values for mandibular symphysis height (IIiMe) were 46.97 mm and 42.58 mm, respectively, in both males and females. On average, male mandibular symphysis was 10% higher than female symphysis, and this finding was statistically significant ($p < 0.00$). Therefore, the height of the mandibular symphysis was considered a distinguishing criterion between the genders (Table 4).

Facial type

Facial type had no correlation with the FMIA, SfMe.GoMe or Pog'Sn (perpOrPo) measurements. IMPA and Pog'Pog'' measurements were similar for brachyfacial and mesofacial types and LBD measurements were similar for mesofacial and dolichofacial types SfMe.OrPo, BBD, IIiAlIiMe, IIiMe and IIi.MOP were statistically different for the extreme facial types (dolichofacial and brachyfacial) but similar for the mesofacial type (Table 4).

DISCUSSION

This study described the cephalometric characteristics of the mandibular symphysis of a sample consisted of 60 Brazilian Caucasian adults residents of the central region of the country, with an average age of 27 years and 6 months. Subjects presented well-balanced faces and normal occlusion. The measurements analyzed included dentoalveolar, skeletal and soft tissue structures of the mandibular symphysis and the main objective was to evaluate the influence of gender and facial type on the morphology of the symphysis. In this study, the distinction between facial types was made using concordance between facial analysis and the SN.GoGn value. The cutoff value to characterize the mesofacial type was performed with a slight variation (2.0°) from the normative value (32°). Hence, when the facial features were compatible with a SN.GoGn less than 30° , the type was considered well-balanced brachyfacial and dolichofacial when over 34° . From this sample, it can be seen that reading the SN.GoGn angle is quite adequate for evaluation of facial type, just as Tweed suggested in relation to the FMA angle.²⁹ The data obtained

in this study confirmed certain characteristics of the mandibular symphysis already described in the literature, but it also unprecedentedly showed the influence of certain measurements when drawing up individualized therapeutic targets for Brazilians.

Gender

The similarities between male and female mandibular symphyses are evident, except in the case of height. The results in general showed significant morphological similarity between the dentoalveolar and basal symphyses, both in thickness and inclination. The absence of sexual dimorphism for the IMPA angle has also been confirmed by other studies^{17,26} involving normal occlusion.

The expectation of finding a male symphysis statistically more prominent than the female was not confirmed in this study, same findings were previously reported by Scavone et al²⁵ and Arnett et al.² The results confirmed that both the width of the basal symphysis and its anterior projection are similar between the genders. The perception of a more projected mandibular symphysis in males may be explained by a greater vertical tendency and especially by its greater height. On average, the height of the mandibular symphysis in males was 47 mm and 42.5 mm in females. This difference was statistically significant ($p = 0.0$) and can thus be considered a differentiating factor between the genders.

Facial type

In this study, the sample was based on subjects with skeletally well-balanced faces, but with variations in their mandibular plane angles. In addition to a subjective facial analysis, the subjects were categorized into three distinct facial types: dolichofacial, mesofacial and brachyfacial. One of the main objectives of this study was to identify possible variations in the morphology of mandibular symphysis from the premise of a variation in the facial morphology not involving the extremes.

Dolichofacial types presented features well described in the literature,^{5,6,12,27} which include narrower and higher alveolar and basal symphyses with greater lingual inclination of the lower incisors. For this reason, the projection of the long axis of the alveolar symphysis was closer to the Me

point (IIiAIiMe) in the dolichofacial types. These characteristics are typical morphological signs of subjects who are hyperdivergent or also called long faced. This study showed the tendency in the mandibular symphysis morphology in well-balanced dolichofacial type subjects and which probably becomes more accentuated as the vertical gap increases. The average thickness of the alveolar symphysis in the region of the apex of the lower incisors found by Handelman,¹² in 1996, in patients with a high mandibular plane was 5.5 mm. This result was lower than the findings of this study for dolichofacial type people with a well-balanced facial pattern (7.32 mm). However, there were methodological differences between the studies, such as the inclusion of patients with malocclusion, extreme vertical growth patterns and the different criteria for measuring the alveolar symphysis.

After adding the mean values of buccal and lingual thickness (BBD + LBD), the dolichofacial type group showed an average of 7.32 mm, while the average for the mesofacial and brachyfacial type groups was 8.72 mm and 9.94 mm, respectively. These values denote that the alveolar symphysis in the apical region of the lower incisors is on average 20% narrower in dolichofacial types.

For brachyfacial well-balanced faces, the most striking morphological feature was the greater thickness of the bone near the apex of the lower incisors, especially at the lingual region (LBD). In general, the findings of this study are in accordance with the literature in terms of a wider and shorter symphysis, with a greater buccal inclination of the dentoalveolar and basal symphyses for brachyfacial types.

The cephalometric IMPA measurement was influenced by facial type. The mean values were 88.27°, 93.42° and 96.65°, respectively, for the dolichofacial, mesofacial and brachyfacial types. Tweed's concept,^{7,29} is summarized as inclining the incisors and the alveolar portion in the buccal direction as the tendency to grow becomes more horizontal.

In contrast, the FMIA measurement, which evaluates lower incisor inclination in relation to the Frankfurt plane, was less variable with the oscillation of the mandibular plane. According to the results, this angle ranged between 60° and 62° for most patients (Fig 4).

Clinical implications

For the surgical orthognathic planning in cases of menton deformities, a comparison with normative values is needed. Thus, the extent of the surgical movement depends on the pre-surgical measurement of the height and anterior symphysis projection of the face. The height of the mandibular symphysis recommended for male and female Caucasian North Americans is 44 mm and 40 mm, respectively.² This study found higher mandibular symphyses, 47 mm and 42.5 mm, respectively. In other words, a 10% greater proportion for males was maintained, just the absolute value increased.

The expression of a higher mandibular symphysis and a lesser anterior projection in white Caucasian Brazilians contrasts when compared to North Americans. An average position of 6.67 mm below the subnasal line perpendicular to the Frankfurt plane was found, and it is worth noting that no significant difference was found between the genders. In North American Caucasians² the value found was 3.5±1.8 mm for males and 2.6±1.9 mm for females, with a differential methodology in the use of the natural head position. However, the lesser projection of the menton in white Caucasian Brazilians has also been confirmed by other studies^{15,25} (Fig 5).

Because of this difference, the use of normative value guideline of samples from North American Caucasians has been questioned for therapeutic application in white Brazilians.²⁵ This statement can be partly explained by the difference in ethnic origin, as white Brazilian are descendents of people from Mediterranean countries, such as Portugal, Italy and Spain, whereas North American Caucasians are mainly of English, Polish, Dutch, Scottish and French origin. Ethnic and individual diversity in human facial contours in Caucasians from different countries means that normative values²⁵ cannot be applied universally. Another reason to justify this difference is the criterion used for sample selection. Arnett et al² formed a sample with photographic models, unlike this study and others^{15,25} whose basis for selection was well-balanced faces, not always associated with beauty. Hence, it is essential to individualize orthodontic planning according to the population group being analyzed.

The thickness of the dentoalveolar symphysis is another feature of clinical relevance and its

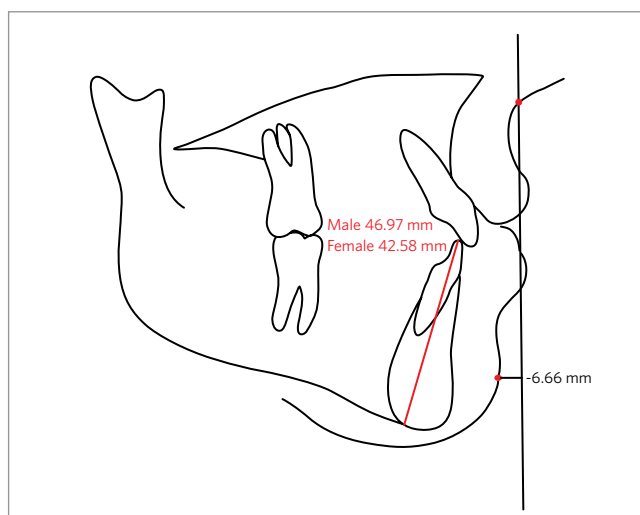


Figure 5 - Menton projection and mandibular symphysis height mean values proposed by this study.

evaluation can establish the extent of safe orthodontic movement of the lower incisors, such as projection and retraction.^{24,28} The possibility or lack of possibility of this orthodontic movement helps in making decisions for borderline cases undergoing orthodontic treatment with or without tooth extraction or in the treatment of skeletal sagittal discrepancies with compensation or with orthognathic surgery.¹² Buccal and lingual corticals at the level of the incisor apex may represent the lower anatomic limits for orthodontic movement, since there is no bone apposition^{12,20,28}. When tooth movement exceeds the limits imposed by the alveolar symphysis morphology, there could be a risk of instability or iatrogenesis.^{12,20,30} Hence, severe skeletal discrepancies in narrow alveolar symphyses limit orthodontic compensation and require orthognathic surgery. This concern about mandibular symphysis thickness is particularly acute in dolichofacial types. With the lesser alveolar thickness, subjects with vertical growth are naturally more limited in terms of sagittal orthodontic movement. An example of this clinical difficulty is the planning of this orthopedic treatment in cases of Class II malocclusion with mandibular deficiency and accentuated vertical growth. Mandibular growth with clockwise rotation complicates

orthopedic mandibular correction and requires a compensatory projection of the lower incisors in a narrow symphysis. The periodontal prognosis will depend on the quality of local hygiene and mainly on marginal gingival thickness.^{3,19,31}

Orthodontists have traditionally evaluated lower incisor positioning using angular and linear cephalometric measurements. It is important that a morphological analysis of the dentoalveolar symphysis be added to this simplistic geometric analysis. For this reason, computed tomography to evaluate buccal-lingual bone volume and density in the alveolar region of the symphysis prior to orthodontic treatment has become increasingly common.^{11,18,19,21,24}

Considering these facts and recognizing the undeniable importance of the mandibular symphysis for orthodontic treatment, this study has emphasized the need for individualization. It can be concluded that even for well-balanced facial patterns, some morphological variations are influenced by gender and facial type.

CONCLUSIONS

Based on these results and in accordance with the methodology used, it was concluded that:

- » Mandibular symphysis height was a differentiator between the genders and was, on average, 10% higher in males.
- » The degree of divergence of the mandibular plane tended to influence the inclination of the dentoalveolar symphysis but not that of the basal symphysis.
- » Well-balanced dolichofacial types have a narrower mandibular symphysis in the alveolar and basal portions and a greater dentoalveolar lingual inclination.
- » Well-balanced brachyfacial types have a thicker mandibular symphysis in the alveolar and basal portions and a greater dentoalveolar buccal inclination.
- » The soft tissue projection of the chin was on average 6.66 mm below the subnasal vertical line and there was no distinction between the genders and facial types.

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Evaluation of the lower incisor inclination during alignment and leveling using superelastic NiTi archwires: A laboratory study

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Objective: The aim of this laboratory study is to evaluate the influence of the shape and the length limitation of superelastic nickel-titanium (NiTi) archwires on lower incisors inclination during alignment and leveling.

Methods: Metal teeth mounted on a typodont articulator device were used to simulate a malocclusion of the mandibular arch (-3.5 mm model discrepancy). Three different shapes (Standard, Accuform and Ideal) of superelastic NiTi archwires (Sentalloy, GAC, USA) were tested. Specimens were divided in two groups: Group I, with no limitation of the archwire length; and Group II, with distal limitation. Each group had thirty specimens divided into three subgroups differentiated by the archwire shape. All groups used round wires with diameters of 0.014-in, 0.016-in, 0.018-in and 0.020-in. The recording of all intervals was accomplished using standardized digital photographs with orthogonal norm in relation to median sagittal plane. The buccolingual inclination of the incisor was registered using photographs and software CorelDraw.

Results: The results were obtained using ANOVA and Tukey's test at a significant level of 5%. The inclination of the lower incisor increased in both groups and subgroups. The shape of the archwire had statistically significant influence only in Group I – Standard (11.76°), Ideal (5.88°) and Accuform (1.93°). Analyzing the influence of the length limitation, despite the mean incisor tipping in Group II (3.91°) had been smaller than Group I (6.52°), no statistically significant difference was found, except for Standard, 3.89° with limitation and 11.76° without limitation. The greatest incisor tipping occurred with the 0.014-in archwires.

Keywords: Arch shape. Superelastic NiTi archwire. Arch length. Incisor tipping.

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INTRODUCTION

Attention has been focused on the position of the lower incisors in Orthodontic diagnosis and treatment planning because of its effect on aesthetics, periodontal health, long-term stability and even on the space available in the mandibular arch.²⁰ In the light of increasing use of fixed appliances, notoriously among adult patients, whenever the planning allows, the option must ensure the preservation of the greatest number of teeth, minimizing the extractions. This treatment option leads to major changes in the buccolingual inclination of the lower incisors, which results in greater care in the diagnosis of the final incisor position and in the treatment plan execution.

Nickel-titanium (NiTi) wires were introduced to the market in the late 70's. Later in the 80's, were launched the superelastic NiTi archwires and in the 1990s the superelastic thermal-activated NiTi.⁹ The superelastic NiTi archwires have been proposed for the initial phase of alignment, because of its unique property of memory and superelasticity.¹⁴

Maintaining patient's original arch form during the orthodontic treatment is recognized essential to achieve long-term stability.^{6,10,11,21} The major disadvantage of NiTi archwires is the lack of formability,¹⁸ which doesn't allow conforming the orthodontic archwire under the patient's arch. Different shapes of pre-contoured archwires have been introduced, enabling the practitioner to select the arch according to the patient's at the beginning of the treatment.

With the convenience and popularity of superelastic NiTi archwires, its indiscriminate use has increased, leading to the questioning of two fundamental orthodontics principles: maintaining patient's original arch form (stability) and labial inclination of the teeth (periodontal health).

Numerous studies^{6,8,11,21} have been conducted on the changes of mandibular arch, especially the lower incisors, in order to quantify the effects on the stability and periodontal health. These changes can be easily detectable and measurable, however, it is difficult to correlate them because of the innumerable variables present in a clinical study, such as the malocclusion, orthodontic mechanics, sex, gender, duration of treatment. Based on this premise, the present study was conducted using

a Typodont simulator with standardized malocclusion, testing two variables, the shape and the length limitation of the NiTi archwires.

The purpose of this laboratory study is to evaluate the influence of the shape and the limiting of the length of superelastic NiTi archwires on the lower incisors inclination during the alignment and leveling.

MATERIAL AND METHODS

Metal teeth mounted on a Typodont articulator (3M/Unitek, 611-500), previously banded with brackets slot 0.022 x 0.028-in (Morelli, Edgewise/Standard - 10.30.901) was used to simulate the lower arch malocclusion. The left lower central incisor, additionally received the establishment of a steel wire segment (0.019 x 0.025-in and length of 2 cm) parallel to the long axis of the tooth crown, distally to the bracket (Fig 3). This procedure allowed the registration of the incisor buccolingual inclination at all stages of the alignment. The teeth were mounted with a discrepancy of -3.5 mm (Fig 1E) and absence of Spee curve (Fig 3).

A condensation silicone (Resi-Line Commercial LTD) impression was performed on the lower arch simulated. After that, the metal teeth could be repositioned, allowing the 60 times malocclusion replication needed (Fig 1).

Three different shapes of pre-contoured superelastic NiTi archwires (*Sentalloy - Psychic Force Mandibular Arch*, GAC Inc) were tested (Fig 2). The sample was divided into 2 groups: Group I, without distal limitation on the length of the archwire and Group II, limiting the length of the archwire with a distal bend (Fig 3). Each group was composed of 30 specimens that were divided into three subgroups according to the shape of the archwire: 10 Standard (Code 02-510-6), 10 Accuform (code 02-511-6) and 10 Ideal (code 02-517-6). In all 60 replicated malocclusions were used a sequence of round continuous archwires 0.014-in, 0.016-in, 0.018-in and 0.020-in for the alignment and leveling of the teeth.

Elastomeric rings (59-100-70, GAC) were used to tie the archwire. The only difference between groups I and II was limiting or not the archwire length (Fig 1). In Group I, the archwires were let free after the second molar tube and in Group II, the archwires were previously heated at each end for 5 seconds with a Blazer (Blazer Products Inc.),

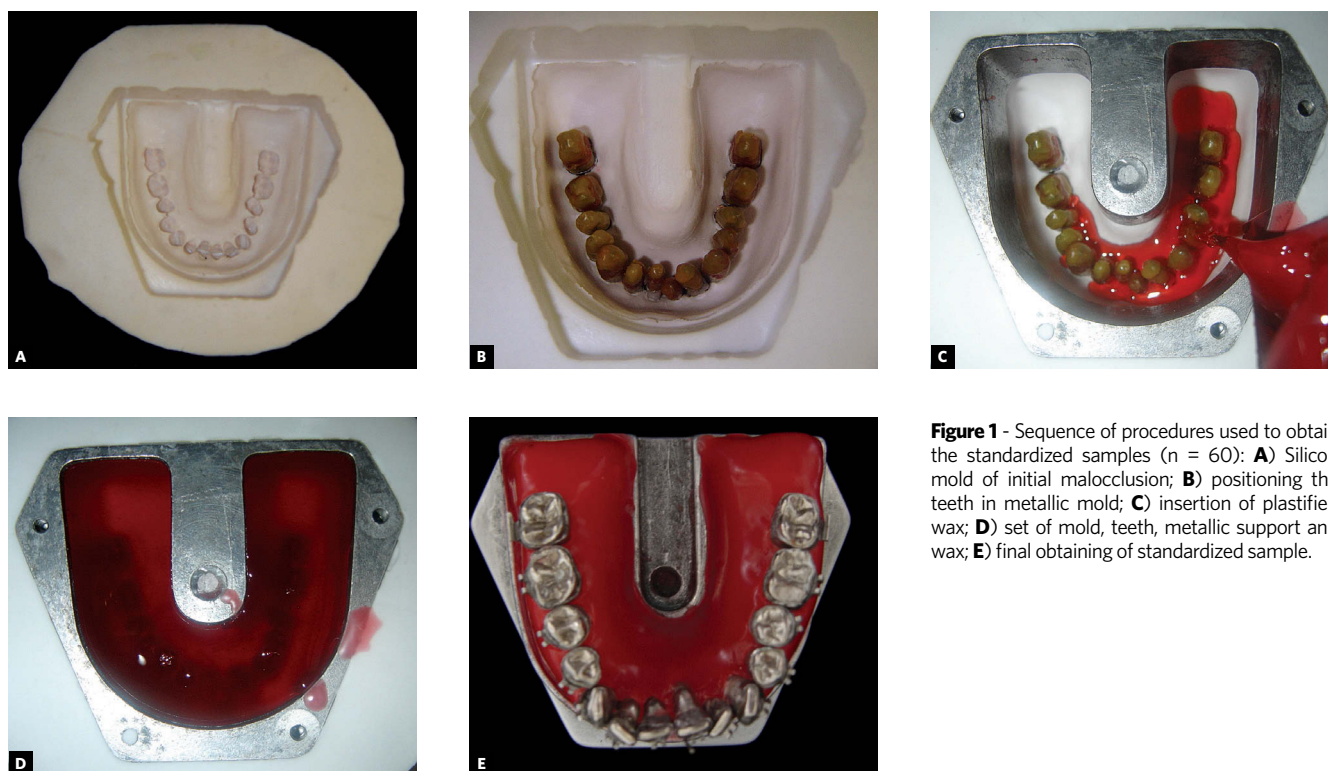


Figure 1 - Sequence of procedures used to obtain the standardized samples (n = 60): **A:** Silicon mold of initial malocclusion; **B:** positioning the teeth in metallic mold; **C:** insertion of plastified wax; **D:** set of mold, teeth, metallic support and wax; **E:** final obtaining of standardized sample.

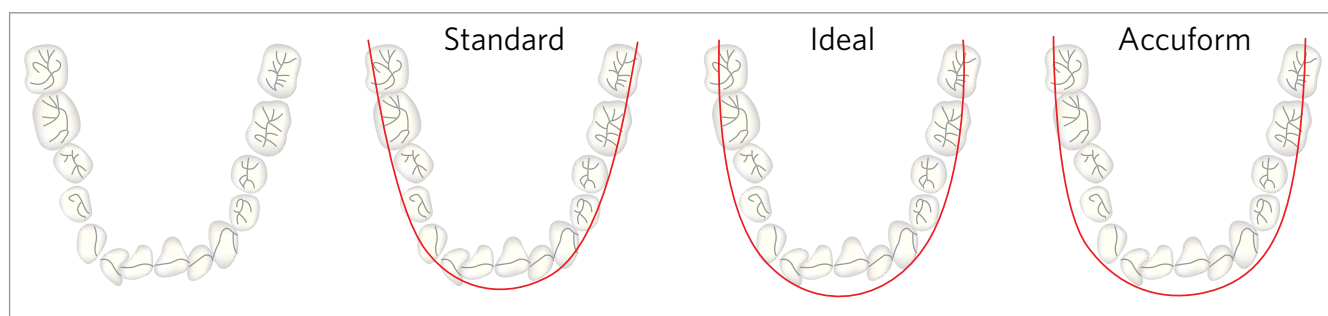


Figure 2 - Illustration of pre-contoured archwires shapes used.

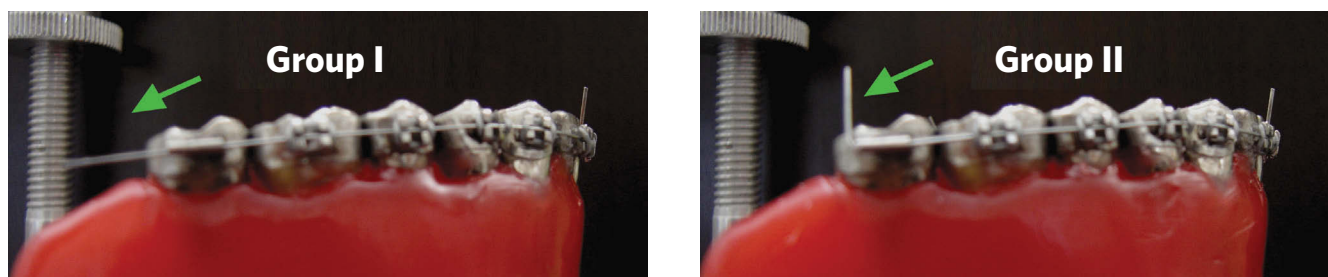


Figure 3 - Segment of steel wire was added parallel to the long axis of the crown of the left central incisor. The green arrow indicates the difference between groups: Group I, the length of the arch was not limited; Group II, there was limitation on arch length.

insert into the tube and bent distally with a special instrumental (Morelli, 75.02.022). The typodont was then immersed in warm water (50° C), controlled by thermostat, and tooth movement was possible (Fig 4). Two immersions were realized for each archwire diameter. The immersion time was standardized for 4 minutes at 50° C with 30-second interval between them in water at 25° C.

The record of all stages (initial, 0.014-in, 0.016-in, 0.018-in and 0.020-in) was realized by means of digital photos (Sony/Cybershot 5.1 MP) standardized in orthogonal norm to the midsagittal plane

(Figs 5 and 6). It was obtained a total of 300 photographs (60 samples x 5 stages records).

The inclination of the lower incisor was measured on the photographs using the software Corel Draw, version 13 (Fig 6). After realized and collected all the measurements the ANOVA test was performed to determine the behavior of the groups. It was tested the differences among the shapes of the archwires, the length limitation and the interaction between them. A subsequent Tukey's post hoc test was used to identify intra-group and inter-group statistical significant differences ($p < 0.05$).

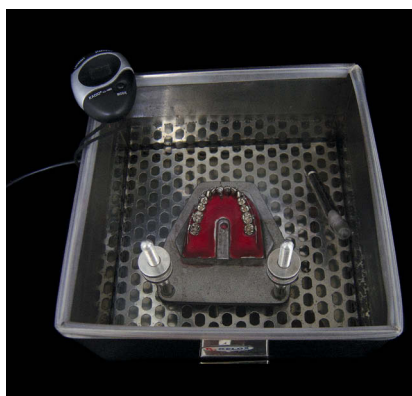


Figure 4 - Simulator submerged in warm water (50° C) controlled by a thermostat and a timer to allow tooth movement.



Figure 5 - Wooden device to standardize the registration of the phases (initial, 0.014-in, 0.016-in, 0.018-in and 0.020-in) by means of digital photographs in the orthogonal norm to the sagittal plane.

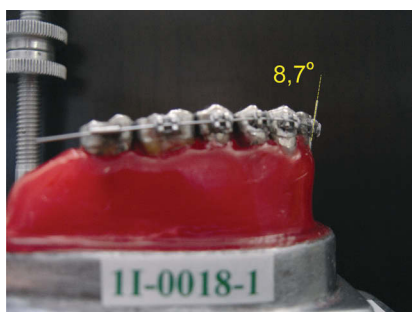
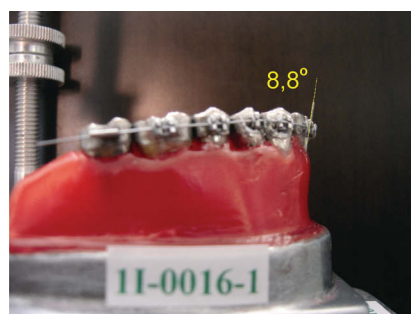
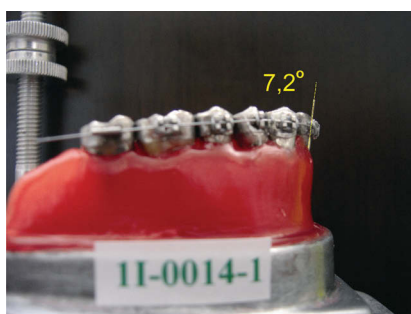


Figure 6 - Sequence of photographs to obtain lower incisor tipping at all stages (initial, 0.014-in, 0.016-in, 0.018-in and 0.020-in).

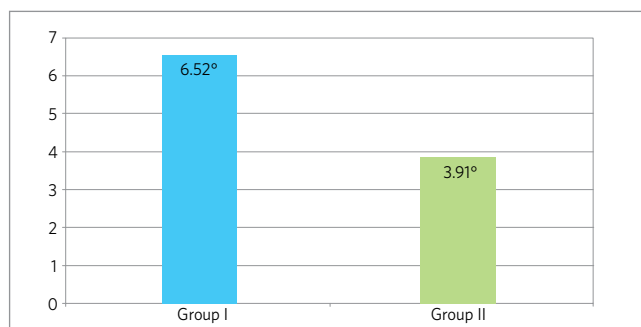


Figure 7 - Mean inclination of the lower incisor (degrees).

Table 1 - Mean difference between the final and the initial position (degrees) of the lower incisor (ANOVA).

Difference between initial and final inclination of the lower incisor			
Binding	Standard	Ideal	Accuform
Group I	11.76 ^{aA}	5.88 ^{bA}	1.93 ^{cA}
Group II	3.89 ^{aB}	3.54 ^{aA}	4.29 ^{aA}

Same lower-case letter (a, b, c) in the same row represents similarity ($p > 0.05$) among the means.

Same caps letter (A, B) in the same column represents similarity ($p > 0.05$) between the means.

Table 2 - Mean inclination of the lower incisor during the tested intervals in the different subgroups (Tukey's test).

Subgroups	Intervals			
Group / Archwire shape	0.014-in — Initial	0.016-in — 0.014-in	0.018-in — 0.016-in	0.020-in — 0.018-in
Group I / Standard	7.45 ^a	1.02 ^b	1.14 ^b	2.15 ^b
Group I / Ideal	7.43 ^a	-0.15 ^b	-1.19 ^b	-0.21 ^b
Group I / Accuform	3.81 ^a	-0.77 ^b	-0.16 ^b	-0.95 ^b
Group II / Standard	3.91 ^a	0.74 ^b	-1.00 ^b	0.24 ^b
Group II / Ideal	3.93 ^a	-0.34 ^a	-0.40 ^a	0.49 ^a
Group II / Accuform	4.48 ^a	0.27 ^b	-0.62 ^b	-0.27 ^b

Same lower-case letter (a, b) in the same row represents similarity ($p > 0.05$) among the means.

RESULTS

Buccolingual inclination of the incisor increased in both groups regardless of the archwire shape and limited or not the archwires length (Table 1). The mean inclination of the lower incisors in Group I (without limitation) was 6.52° and in Group II (with limitation) was 3.91°, however, this difference was not statistically significant (Fig 7).

When the archwire shapes were evaluated, the Group I (without limitation) showed mean inclination of the lower incisor increased of 11.76°, 5.88° and 1.93°, respectively to the Standard, Ideal and Accuform. However, in Group II (with limitation) the increase of the incisor inclination was not statistically significant among the archwire shapes (Standard = 3.89°, 3.54° = Ideal; Accuform = 4.29°). Analyzing individually the limitation or not of the archwire length, the only statistically significant difference was with the Standard shape (with limitation = 3.89°; without limitation = 11.76°) (Table 1).

Table 2 showed that in all subgroups the greatest change in the inclination occurred after the use of 0014-in archwire, except for the subgroup Ideal with limitation that showed no statistically significant difference among the different archwires diameter.

DISCUSSION

This study showed that regardless of the shape and length of the archwires used the buccolingual inclination of the incisors increased. This suggests that when there is lack of space in the lower arch, alignment and leveling using superelastic NiTi archwires causes labial tipping of the lower incisors. In a clinical study using lateral cephalometric radiographs, Pandis, Polychronopoulou and Eliades¹⁷ also found increased of the labial inclination of the mandibular incisors during the leveling of lower arch when a lack of space was observed, regardless of the bracket system used.

The effect of lower incisors labial tipping on the periodontium remains controversial. While Little, Riedel and Stein¹³ showed association between gingival recession and labial movement of the incisors, other authors did not found association.^{1,7,19} Yared, Zenobio and Pacheco²⁴ evaluated the periodontal condition of lower incisors moved labially during orthodontic treatment and found no correlation between proclination and gingival recession. They also concluded that greater incisor tipping is acceptable, reducing the risk of periodontal damage, when the incisors are not proclined in the beginning of the treatment, so the incisor position at the end of the treatment is more important

than the tipping amount during the treatment. Djeu, Hayes and Zawaidesh⁷ also found no correlation, however, they underline the importance of determining how much tipping could be achieved with fixed appliances before gingival recessions begin to appear.

The indiscriminate use of pre-contoured archwires during alignment can cause damage to the patients, as comes to facial aesthetics, periodontal health and even compromising the stability of the treatment. Thus, a careful evaluation to obtain an accurate diagnosis and treatment plan must be prior established to determine when it is possible and necessary to tip the incisors buccally and when this should be avoided.

In cases of severe overjet and anterior crowding, lower incisors proclination can be a valuable alternative to avoid extraction, particularly in critical facial profile cases.¹⁶ Artun and Grob  ty³ concluded that pronounced advancement of the mandibular incisors may be performed in Class II adolescent patients with dentoalveolar retrusion without increasing the risk of recession. Increased proclination may also be a treatment option of presurgical orthodontic decompensation on lower incisor inclination in Class III patients undergoing for mandibular orthognathic surgery. It was reported that adults patients who required more than 10  of lower incisor proclination during the pre-surgical decompensation, this expansion was accompanied by significant risk of gingival recession, especially when the alveolar process was thin.³

Both, the lack of difference in the long-term stability among extraction and non-extraction cases⁸ and the fact that clinical measurements undertaken in mandibular orthognathic surgical patients showed no association between incisor inclination and long-term incisor irregularity² have further weakened the argument against proclination.

It is unknown the amount of crowding that can be solved with teeth inclination and/or expansion and that would be still considered stable. Tanaka, Ribeiro and Mucha,²² in a literature review on the importance of the maintenance of the lower arch form, found considerable controversy on dental expansion. It is said that the shape of the patient original lower arch seems is the best guide for long-term stability. However, even minimizing changes during the treatment there is no stability guarantee.⁶ In cases where incisor inclination and/or expansion are required,

the use of permanent retainer could be an option to the lower anterior alignment maintenance,^{12,13}

There is a range of arch shapes within population,^{5,15} The literature reported that the main shapes found in untreated individuals are tapered, ovoid and average.^{4,23} According to Taner et al²³ most of mandibular arches shows tapered shape before orthodontic treatment. In our study, the format standard was the most similar to the malocclusion arch simulated. The results showed that the greatest labial tipping of the incisors occurred when the shape standard was used. This result showed that only choose the most closely arch wire shape does not mean that the lower incisors will not be affected, so it is important to underline that the choice or construction of the arch wire according to the original patient dimensions (intercanine and intermolar) does not exclude the need of an accurate diagnosis and detailed treatment plan to achieve the desirable incisor position.

The archwire shape influenced statistically significant the incisor inclination in Group I (Table 1). The incisors have the highest labial tipping with the Standard shape and the lowest with the Accuform. Comparing the both shapes (Fig 2), it is possible to note that the Standard shows the intercanine region more contracted, while the Accuform, this same region, is more expanded. This may have allowed further expansion in the canines region and lower labial inclination of the incisor during alignment.

Another important finding in this study was that the greatest amount of incisor tipping occurred in the first phase of the alignment and leveling with the 0.014-in archwires, regardless of the shape and the length. This suggests that when no incisor proclination is desired, care must be taken from the first archwire used for the alignment and leveling.

It is believed that the length limitation of the archwire, distal bending or tying, prevents the incisor proclination. However, this fact is based on clinical experience and not scientific based, because the literature is still scarce on this topic. In our study, both groups showed labial inclination of the incisors. Despite the mean inclination of the lower incisors had been lower in the Group II (with limitation), this difference was not statistically significant.

Clinical studies are suggested to test the effectiveness of the archwire length limitation on

incisor proclination. The method used was not efficient in this study, because even limiting the archwire length, labial inclination occurred. The distal bend realized did not prevent the slippage of the archwire during the alignment and labial inclination of the incisors occurred. Thus, when labial tipping is not required another method should be taking into account during the planning of the case.

CONCLUSION

According to the methods it can be concluded that:

- » Lower incisors tipped buccally regardless of the shape and the length of the superelastic NiTi archwires used.

- » Despite the mean incisor labial inclination found using archwires with length limitation (Group II) was lower than no limitation archwires (Group I), no statistical difference was found.
- » Superelastic NiTi archwire shape only showed significant influence on the final inclination of the incisor when the archwires were not distal limited.
- » The highest proclination of the incisor occurred when the Standard archwires were used.
- » Regardless of shape and length, the higher degree of incisor inclination occurred in first stage of the alignment and leveling.

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Snoring and Obstructive Sleep Apnea Syndrome: A reflection on the role of Dentistry in the current scientific scenario

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Introduction: Finally the dentist has awoken to the fact that by being a health professional, he has as primary function to take good care of the welfare of patients. In face of this challenge, the dentist starts to understand his role in the treatment of snoring and of obstructive sleep apnea and hypopnea.

Objective: The current paper has the purpose of discussing the role of this professional in the diagnosis and treatment of these diseases, most specifically of the therapy involving inter-occlusal devices, emphasizing the importance of multidisciplinarity in the reestablishment of the quality of life of the patient.

Keywords: Snoring. Obstructive sleep apnea and hypopnea. Occlusal plates.

INTRODUCTION

Among all sleep disorders, Obstructive Sleep Apnea-Hypopnea Syndrome (OSAHS) is the most prevalent one, diagnosed in 67.8% of the individuals referred to 19 centers of sleep evaluation.¹ The OSAHS is a chronic disease, progressive and disabling, characterized by partial or total obstruction of the upper airway during sleep.² In middle-aged individuals the prevalence is 2% to 4%,³ more frequently seen in men, reaching 10 to 20% of them.⁴ Excessive daytime sleepiness, snoring,

respiratory pauses, restless sleep with multiple micro-awakenings, morning headache, neurocognitive deficits, personality changes, reduced libido, depression and anxiety are common symptoms of this disease, causing emotional, social, occupational and marital damage.⁵

Even though its impact in public health may be overestimated, there are evidences of the association between hypertension⁶ and OSAHS, CVD⁷ and greater risks of car accidents.⁸ As for its progressive character, the treatment of this syndrome is not

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

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indicated only by the relief of symptoms, but also to decrease the risk of death⁹ and also by the savings of resources spent with health services.¹⁰

Dentistry is living a new era and crossing new frontiers, studying disciplines related to the overall health of the individual, highlighting the need of knowledge about sleep and its influence upon health and quality of life of individuals. Every dental surgeon plays an important role in identifying patients with sleep disorders, particularly snoring and OSAHS. Therefore, it seems to us, that a reflection on the role of dentistry is necessary for the diagnosis and treatment of this disease in the current scientific context.

CONCEPTS AND PATHOPHYSIOLOGY OF SNORING AND SLEEP APNEA

Snoring is a sign of different disorders. It's originated from the partial collapse of the tissues involved in the passage of air through the upper airway. A muscular tonus change in this region, results in a failure of maintaining the proper space for the airflow, specially in the deepest stages of sleep, is an important cause of snoring in adults. Unfortunately, this inappropriate muscular tonus is not very evident when in vigil. Tissue masses that obstruct the airflow, such as the increase in volume of the tonsils and adenoids, cysts, tumors, anatomical changes, as retro and micrognathia, nasal septum deformities, sinusitis and polyps are factors to be considered in the collapse of the upper airways. The fat accumulation in the neck region is relevant in breathing obstruction, meanwhile, a large cervical circumference is, by itself, an important data for the diagnosis of snoring. Similarly, conditions such as Down's syndrome and acromegaly, that are able to increase tongue size, also contribute to the presence of snoring. The restriction of the airflow through the nose increases the negative pressure during inspiration, causing partial collapse of the passage of the air flow. This would explain the common observation of people that usually do not snore, shall do so when they have flu or an allergy crisis.¹¹

All airflow disruption that lasts two complete respiratory cycles is called apnea. The hypopnea is identified as the partial obstruction of more than 50% of the air flow.

Both can present variable lengths between 10 to 50 seconds. The OSAHS is classified according to the number of apnea episodes per hour: Slight (from 5 to 15 episodes of apnea/hour), moderate (from 15 to 35 episodes of apnea/hour) or severe (over 30 episodes of apnea/hour), the occurrence of up to 5 events per hour is considered normal.¹² It must be pointed out that the central apnea mediated by the central nervous system, under no circumstances, can be treated as obstructive, the polysomnographic examination, so far, is the diagnostic method capable of distinguishing these two diseases. Even within this context, it is important to mention the mixed apnea, called this way by starting as central and then becoming obstructive. It occurs when the breathing movements are restarted at the end of central apnea but the upper airway is obstructed.¹¹

The Upper Airway Resistance Syndrome (UARS) is a syndrome of an increase in the upper respiratory tract collapse during sleep, with intermediate values among healthy subjects and with slight or moderate OSAHS.¹³ From the physiological point of view, patients with UARS and with OSAHS are similar, differentiating only by the severity of the airway collapse during sleep. The following symptoms and comorbidities are: Fatigue, insomnia, non-restorative sleep, aching body, headache, depression and hypertension. Both result in awakenings and sleep fragmentation. However, due to differences in epidemiology of these diseases, there is still controversy if the UARS is a separate entity or an early stage of the OSAHS.¹⁴ As well as the OSAHS, the UARS is debilitating and shows a progressive character, where the majority of patients who have had a diagnosis of UARS and remained untreated during 4 years showed a worsening of the symptoms of insomnia, fatigue and depression, with an expressive increase in prescription drugs, like antidepressants, hypnotics and humor moderators.¹⁵

DIAGNOSIS AND CLASSIFICATION

The diagnostic methods used for sleep disturbances investigation range from a subjective evaluation, by means of specific questionnaires, to the daytime or nocturnal polysomnographic or actigraphic records. The nocturnal polysomnography study is the gold standard method for the diagnosis of sleep disorders, registering: Electroencephalogram (EEG),

electrooculogram (EOG), electromyography (EMG) of mentum and members, oronasal flow volume, thoracoabdominal motion, electrocardiogram (ECG) and pulse oximetry.¹⁶

The dental surgeon can help diagnosing sleep disturbances referring to a specialist in sleep medicine. A special attention is given to frequent history of morning headaches, a common symptom in 18% of the snoring or OSAHS patients in comparison to a 5% in the general population.¹⁷ Besides, during the clinical examination one can recognize buccal manifestations of OSAHS and snoring in the oropharynx region, tongue, uvula, soft palate and tonsils.¹⁸

To account these considerations, it is recommended that the size and conditions of the tongue should be evaluated. The Mallampatt index, used by the anesthesiologists to determine the intubation difficulty, may serve as an indicator of air passage obstruction by the tongue volume. It is also known that the tonsils size have a direct relation with OSAHS, once this volume increase can promote reduction of air passage. The observation of shape and volume of uvula and soft palate can not be neglected, as well as the mandibular position, both vertically and horizontally.¹⁸ One should also evaluate the age, taking into account that muscular tonus decreases with age. It is worth noting the relevance of evaluation the weight, since obesity plays a preponderant role¹⁹ and contributes to the increase of the cervical circumference. Also in this aspect, it is suggested that hereditary characteristics and biotype be considered, once they are important factors, without necessarily been obese.²⁰

Regarding the mandibular posture, radiographic and tomographic images are used to evaluate and to quantify the bone structures of the skull, mandibular and hyoid bone positions. In these images, some soft structures like the tongue and soft palate can be assessed too. When compared to the control group, OSAHS patients presented small and retro-positioned mandibles, with subsequent narrowing of the posterior space for the air passage, tongue increment, flaccid soft palate, lower positioning of hyoid bone and repositioning of the maxilla.²⁰

Although its is not the chief complaint, the snoring is the characteristic of OSAHS in children. Breathing difficulties during sleep, headache upon awakening,

abundant sweating, excessive thirst upon awakening, nightmares, sleep terror, nocturnal enuresis, little restorative sleep, excessive sleepiness during the day, hyperactivity, attention disorders, poor school performance, behavior disorders, aggressiveness, frequent infections of the airways, frequent otitis and obesity also can be symptoms of OSAHS in children. The most common cause of this disorder in children and adolescents are hypertrophied tonsils and adenoids, but one should also be aware of malformation of the maxilla and / or mandible. In severe cases, pulmonary hypertension and *cor pulmonale* may be developed.⁶ It is important that the association of apnea with facial dysmorphism calls the expert's attention to an early diagnosis of risk factors for OSAHS and its correct treatment, when dental interventions can be corrective for craniofacial deformations. Nasal obstruction is an initial determining factor in the mouth breathing, and consequently, the change in position of the tongue and teeth in the mouth. Such factors determine functional and structural changes in the face, like hypoplasia of the frontal sinuses, interocular reduction, reduction of the nasal size with collapse of the nasal valve, reduction of the dimensions of the hard palate and consequent reduction of upper arch, leading to a deficient nasal breathing. Mouth breathing, in turn, leads to an increase in volume of the tongue, soft palate and uvula. This frame of facial dysmorphism is called Long Face Syndrome, characterized by a long and narrow face, retrognathia, micrognathia and high and narrow hard palate.

AVAILABLE THERAPIES

The treatment of OSAHS may involve from simple procedures to complex surgical procedures. The reduction in weight may result in a significant reduction in the frequency of OSAHS and snoring, improvement in the sleep architecture and reduction of excessive daytime sleepiness.¹⁹

It is well known that alcohol ingestion can cause or exacerbate snoring, increase the frequency and duration of OSAHS episodes, as well as decrease the saturation of oxygen in the blood,²¹ may be caused by the increased upper airway resistance and the reduction of the tonus of the musculature involved. There are reports of increase of the upper airway collapse during sleep in snorers and

non-snorers individuals, after alcohol ingestion its deleterious effects are directly related to the time elapsed between the ingestion of the drink and the time of the to go to sleep. Thus, individuals should be advised to not consume alcohol within 3-5 hours before bed time.²¹

There is a consensus in the literature that the CPAP/CFLEX (*Continuous Positive Airway Pressure*) is the most effective treatment in controlling sleep apnea and on improvement of oxygenation (Fig 1), specially in patients with severe sleep apnea, by generating a continuous or intermittent positive air pressure.^{5,22} Because of its high cost and of the discomfort that comes from its use, it is considered excessive for the treatment of snoring. In addition, patients who use CPAP can present problems in the TMJ's if the mask is used too tight.¹¹

The surgical technique – uvulopalatopharyngoplasty, too defended before, showed less effective

and with more long-term side effects than the use of oral appliances,^{5,22,23} as well as the use of drugs, which have not yet showed sufficient evidence to be recommended for the treatment of obstructive sleep apnea.²⁴

Oral appliances are a viable and effective alternative, even when compared to the CPAP in random and controlled clinical trials,^{25,26,27} specially in the treatment of those individuals carrying OSAHS that do not adapt to the use of the apparatus before mentioned.^{5,22} They are usually recommended to patients with slight or moderate OSAHS, however, success in the treatment of severe sleep apnea have already been related.^{2,27} Its indication to teenagers and children still needs a more consistent assessment.⁵

Despite of some advantages over the use of continuous air pressure devices, the indiscriminate use, incorrect or even without any professional follow-up have raised questionings about its indication.⁵

Oral devices operate augmenting the caliber of the upper airways and/or by reducing the obstruction, mostly done in a protrusive position of the mandible, where they may be adjustable or with a preset protrusion amplitude built in its construction (Figs 2, 3 and 4).

In comparison to the effectiveness of the oral devices (75% and 50% of maximum capacity of protrusion) the ones constructed with a greater mandibular advancement presented the best results.²² Another category of devices are the tongue retainers with its mechanism of action still unknown and are less used than those with mandibular protrusions.

Pain in the temporomandibular joints (TMJs) teeth and muscles, excessive salivation, joint sounds, skeletal and occlusal changes are some of the adverse effects or complications from the use



Figure 1 - Simulation of CPAP usage.



Figure 2 - Oral protrusion device for OSAHS treatment.



Figure 3 - Adjustable oral protrusion device by means of an expansion screw.



Figure 4 - Oral device with a pre-set protrusion range.

of oral devices.^{2,5,22,26,27} In some cases, after a period of 8 weeks, these adverse effects have been reported by up to 69% of the sample²⁵ and they seem to be related to the maintenance of a protrusive position of the mandible during long periods of sleep, exerting great stress on the muscles of mastication and TMJs. In the TMJs, it would create a stretch of the retrodiskal ligaments setting off an inflammatory response that could result in arthralgia and joint pain. The musculature would be more susceptible to pain by muscular contraction, spasms or contractures, in addition to tractioning the articular disk anteriorly, which together with the articular ligaments stretch, would increase the possibility of their displacement, causing the onset or exacerbation of articular sounds.

CONDUCT OF TREATMENT PROTOCOL OF OSAHS USING INTRAORAL DEVICES

The treatment protocol for OSAHS and snoring, using oral devices, recommended by the American Academy of Sleep Medicine, establishes the functions and limitations of activity of physicians and dentists. If, after diagnosis by a qualified physician, the treatment should involve the use of oral devices, the patient will be referred to a dentist, together with clinical informations necessary and/or appropriate, including a copy of the polysomnography and the evaluation of excessive sleepiness. Certainly, this professional must have knowledge related to sleep medicine and the changes arising from alterations in its normal architecture, as well as being familiar with the methods of diagnosis and assessments, including, but not limited to: Polysomnographic examination, excessive sleepiness assessment test and pulse oximetry. The dentist shall then evaluate the possibility of use of oral devices taking into account the conditions of the soft tissues within the mouth, periodontal, dental and articular health, presence of bruxism and possible contra-indications for your its use.²⁸ Initial radiographic examination of the teeth and related structures should be requested to facilitate future assessment of possible dental or skeletal changes related to the prolonged use of these devices.²⁷ It is also the dentist's role, the choice of the device to be used among the many developed even though comparisons between the different types of oral devices

are still limited^{7,13} and their technical or drawing conclusions are not yet possible.^{22,27} After the incorporation of oral device, control and adjustments should be done, as well as monitoring of subjective changes in the disease symptoms. Once satisfactory improvements of symptoms are achieved, the patient should be referenced back to the physician, for a new objective clinical evaluation of the results achieved, including a new polysomnographic examination. It seems a worrying fact that in an American study involving 124 members of the *Sleep Disorders Dental Society*, where the majority agreed with the statement that only subjective reports of improvement of the symptoms are not sufficient to ensure success in treatment, only in 18% of cases was carried out a post-treatment polysomnographic examination, even though this same examination was conducted in 95% of patients during the initial evaluation.²⁹

This way, it is our duty to call for a greater commitment of the dental professionals once better results in the treatment of snoring and OSAHS using intraoral devices have been achieved when specialists in sleep medicine and dentists work together effectively.

FINAL CONSIDERATIONS

The dental surgeon can significantly contribute to identify sleep respiratory disorders, including OSAHS. However, it is strongly disagreed with those who, for the simple identification, suggest some sort of therapy. The diagnosis must, mandatorily, be carried out by a team of medical professionals, and may encompass the following specialties: Otorhinolaryngology, Pulmonology Neurology, Psychiatry and others. For its diagnosis it is crucial an polysomnography examination²⁷ and the exclusion of other diseases that can range from simple nasal obstructions and nasal septum deviation, even the presence of tumors and central sleep apnea. Given the exposed, it is clear that OSAHS is multidisciplinary in its etiology and treatment. The authors of this paper emphasize that the diagnosis and treatment must be carried out in an interdisciplinary way and that verification of the diagnosis, as well as the therapy to be applied, must be obligatorily performed by doctor enabled to do so. In other words, although it is the competence of the dental surgeon to identify signs and symptoms of OSAHS, since he is a healthcare professional and as such he

should be aware of the quality of life of his patients, in addition to perform one of the following types of therapy, that is the inter-occlusal devices, he should not, under no circumstances, indicate that treatment without the request and attestation of indication of it by whom have the right and responsibility to indicate.

The effectiveness and usefulness of oral devices for the treatment of snoring and OSAHS are already well established in the current literature. However, definitive conclusions about their design still aren't as well defined, specially when one ponders about the mandibular protrusive position where they are usually made and its possible

implications and undesirable effects, ensuring the need for improvement and/or development of new devices, equally effective and with fewer complications arising from its continued use.

Although already established in the literature a treatment protocol using intraoral devices, establishing the responsibilities of physicians and dentists by giving these professionals a unique opportunity to interact and promote quality of life improvement of these patients, in daily practice it seems that these professionals do not consider this for ignorance or option, contributing in some cases to a less effective treatment.

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Comparative study of classic friction among different archwire ligation systems

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Objective: To describe and compare three alternative methods for controlling classical friction: Self-ligating brackets (SLB), special brackets (SB) and special elastomeric ligatures (SEB).

Methods: The study compared Damon MX, Smart Clip, In-Ovation and Easy Clip self-ligating bracket systems, the special Synergy brackets and Morelli's twin bracket with special 8-shaped elastomeric ligatures. New and used Morelli brackets with new and used elastomeric ligatures were used as control. All brackets had 0.022 x 0.028-in slots. 0.014-in nickel-titanium and stainless steel 0.019 x 0.025-in wires were tied to first premolar steel brackets using each archwire ligation method and pulled by an Instron machine at a speed of 0.5 mm/minute. Prior to the mechanical tests the absence of binding in the device was ruled out. Statistical analysis consisted of the Kruskal-Wallis test and multiple non-parametric analyses at a 1% significance level.

Results: When a 0.014-in archwire was employed, all ligation methods exhibited classical friction forces close to zero, except Morelli brackets with new and old elastomeric ligatures, which displayed 64 and 44 centiNewtons, respectively. When a 0.019 x 0.025-in archwire was employed, all ligation methods exhibited values close to zero, except the In-Ovation brackets, which yielded 45 cN, and the Morelli brackets with new and old elastomeric ligatures, which displayed 82 and 49 centiNewtons, respectively.

Conclusions: Damon MX, Easy Clip, Smart Clip, Synergy bracket systems and 8-shaped ligatures proved to be equally effective alternatives for controlling classical friction using 0.014-in nickel-titanium archwires and 0.019 x 0.025-in steel archwires, while the In-Ovation was efficient with 0.014-in archwires but with 0.019 x 0.025-in archwires it exhibited friction that was similar to conventional brackets with used elastomeric ligatures.

Keywords: Corrective Orthodontics. Orthodontic brackets. Friction.

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

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INTRODUCTION

In the early days of Orthodontics, tooth movements were carried out by means of removable appliances combined with springs and elastics. A major shortcoming of these mechanical devices were undesirable tooth inclinations. Accurate tooth movement control only became possible with the advent of the Edgewise appliance, a historic breakthrough in orthodontics that provided controlled tooth movements by means of orthodontic archwires inserted in bracket slots.

Sliding mechanics between archwire and bracket slot incorporated friction forces into orthodontic practice. Kusy and Whitley¹² classified friction into three major types:

1. Classical friction: Caused by conventional ligation as it compresses the archwire against the bottom of the bracket slot.
2. Binding: Friction produced through deformation of the archwire as it compresses the bracket slot walls.
3. Notching: Friction produced by excessive deformation of the archwire, causing the archwire and bracket to interlock, thereby hindering tooth movement.

Binding is inherent in the dental alignment stage since at this stage the slots are in different planes and thus cause archwire deformation, which in turn produces the forces responsible for tooth movement. On the other hand, classical friction is optional as it is present only if conventional ligatures are used to secure the archwires in the slots.

It is important to control classical friction in order to identify the real magnitude of orthodontic forces delivered to the periodontium, increasing

reproducibility in sliding mechanics.¹² The mechanisms normally associated with classical friction control are self-ligating brackets, which eliminate the need for elastomeric or steel ligatures to hold the orthodontic archwire in the slot.

Designed to be used with conventional brackets, special elastomeric ligatures are another resource geared at reducing classical friction. Their innovative design retains the orthodontic archwire without pressing it against the bottom of the slot. Upon insertion, the central body rests on the buccal surface of the bracket while the extensions are positioned under the tie-wings (Fig 1). In this situation the central portion acts as a cover, closing the slot but leaving the orthodontic archwire loose in the slot. The product is marketed by two companies, i.e., Leone, under the brand name Slide and Tecnident's 8-shaped ligatures (Fig 2).

Classical friction can also be controlled with special brackets that allow one to seat the orthodontic archwire actively or passively according to the insertion site of conventional elastomeric ligatures. An example of special brackets is the Synergy orthodontic appliance, manufactured by Rocky Mountain Orthodontics. Synergy features six tie-wings instead of the four present in twin brackets. For a passive system, one should place a conventional elastomeric ligature under the central tie-wings (Fig 3A). When an active system is desired, a conventional elastomeric ligature is placed under the lateral tie-wings. In this configuration the ligature is made to rest on the orthodontic archwire, compressing it against the bottom of the slot (Fig 3B).

Since different appliances are available for controlling classical friction, the aim of this study was to

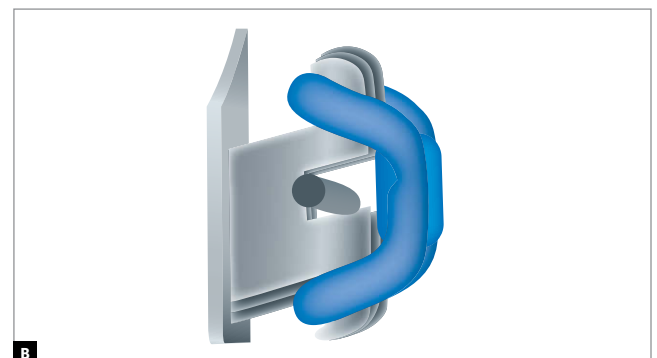
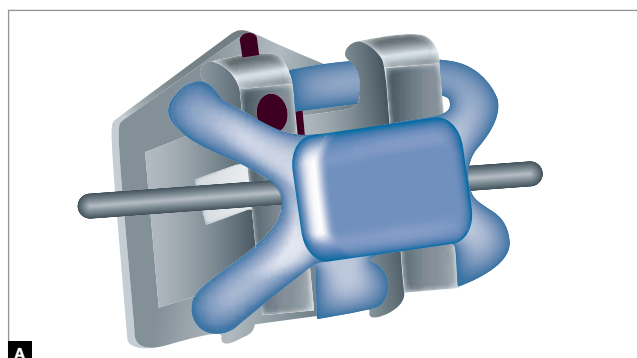


Figure 1 - Slide ligatures: **A)** Frontal view, and **B)** side view. (Source: Catalog Leone Ortodoncia)

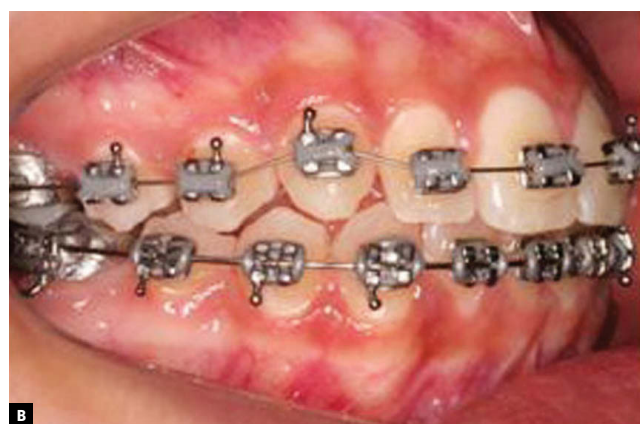


Figure 2 - A) Special 8-shaped elastomeric ligature; **B)** 8-shaped ligature in the upper arch.

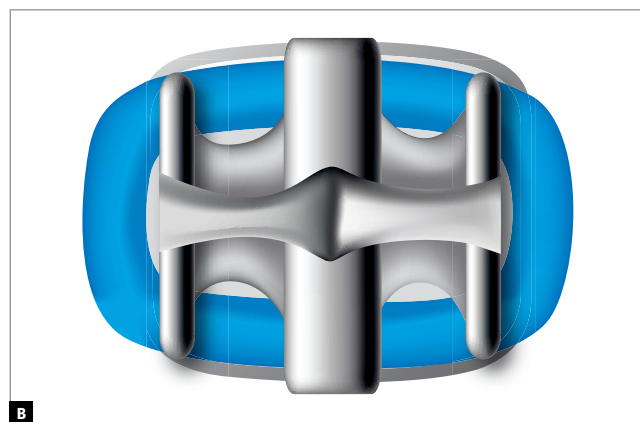


Figure 3 - Synergy bracket: A) Passive system, **B)** Active System. (Source: Catalog Rocky Mountain Orthodontics)

compare the effectiveness of self-ligating brackets, the special Synergy bracket and 8-shaped ligatures in reducing classical friction.

MATERIAL AND METHODS

The following archwire ligation methods were compared:

- » Damon MX (Ormco), Easy Clip (Aditek), Smart Clip (3M/Unitek) and In-Ovation (GAC) self-ligating brackets.
- » Special Synergy brackets (Rocky Mountain) with new elastomeric ligatures tied to the center tie-wings.
- » Conventional twin bracket (Morelli) with 8-shaped ligature (Tecnident).
- » Conventional twin bracket (Morelli) with new

elastomeric ligature.

- » Conventional twin bracket (Morelli) with used elastomeric ligature.

The elastomeric ligatures employed in this study were manufactured by Morelli. They were gray in color and with an internal diameter of 1.2 mm. To simulate the relaxed state produced by the stretching of the elastomeric ligature, ligatures designated as “used” were placed on a cylinder with 3mm diameter, where they remained for 36 hours before being used to tie the wires to the brackets.

First premolar steel brackets with 0.022 x 0.028-in slots were employed. All brackets were bonded to a device with two 0.022 x 0.028-in guiding slots at the ends of the area designed to receive the brackets (Fig 4). Cyanoacrylate was used to perform the direct bonding

of the brackets with the aid of a standard 0.022" thickness ruler simultaneously in the guiding slots and bracket slots (Fig 5).

Tests were carried out on segments of 0.014-in Contour NiTi and 0.019 x 0.025-in steel wire, both manufactured by Aditek. All wires were 12-in long. In each test the wire was stabilized inside the slot by means of covers or clips on the self-ligating brackets, 8-shaped ligatures on the Morelli brackets, new elastomeric ligatures on the center tie-wings of Synergy brackets and new and used elastomeric ligatures on the control twin brackets.

Classical friction forces were recorded during wire traction until total displacement reached 2 mm. A model 5565 Instron universal mechanical testing machine was used with a load cell of 500 Newtons and bridging speed of 0.05 mm/minute. Parallelism between the device and the Instron machine vise was obtained by inserting the tip of a 0.022" standard ruler into the guiding slots while the opposite end contacted the right wall of the vise, which remained stationary. Closing and opening the vise was made possible by lateral displacement of the left movable wall (Fig 6).

The rectangular steel wire was not attached directly to the Instron machine vise in order to prevent any potential friction from being produced by wire torsion (third order friction). The rectangular wire was bent at its end and inserted - in juxtaposition - into the steel tube, which was attached to the vise. Thus, the rectangular wire remained in the bracket slot and loose inside the steel tube, which was pulled through the upper displacement of the Instron machine's crossbar (Figs 7A and B).

Each test was repeated eight times with the wires and elastomeric ligatures being replaced prior to each test. The tests were performed in a dry medium at a temperature between 24 and 26 degrees Celsius.

Before each test, the wire that had been inserted into the slot and attached to the Instron machine was pulled unligated to check whether sliding took place without resistance, which confirmed the absence of binding in the tests.

Means, standard deviations, minimum and maximum friction force values were calculated for each group tested. Comparisons between the archwire ligation systems were conducted using the Kruskal-Wallis test as well as multiple non-parametric analyses with a 1% significance level.

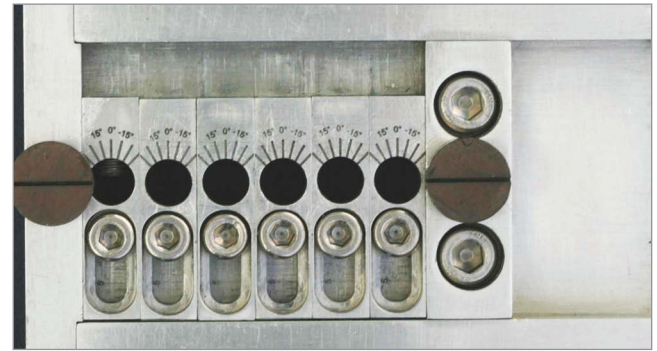


Figure 4 - Device with guiding slots at both ends.

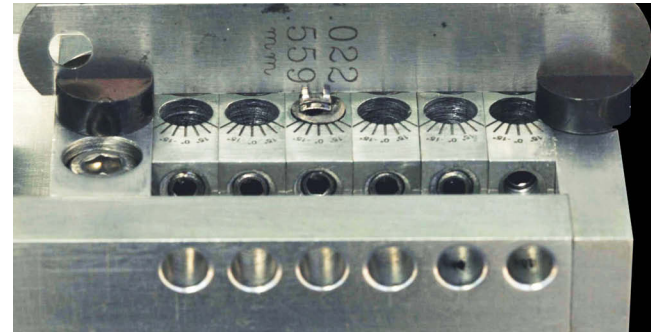


Figure 5 - Placement of the bracket on the device.



Figure 6 - Device positioning and 0.014-in contour NiTi wire on the Instron machine.

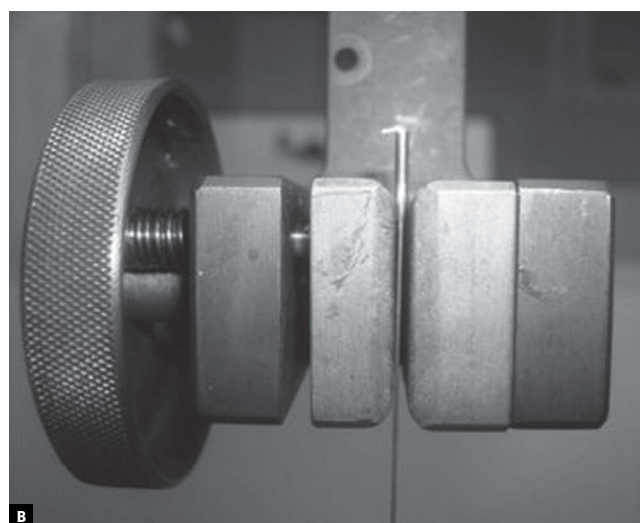


Figure 7 - **A)** Set comprised of 0.019 x 0.025-in rectangular wire and steel tube; **B)** set positioned on the vise.

RESULTS

The descriptive analysis of classical friction in 0.014-in Contour NiTi wires is shown in Table 1. The archwire ligation methods were distributed across three groups (A, B, C) according to statistically significant differences. Group A: Damon MX, Easy Clip, In-Ovation, SmartClip and Synergy brackets, and 8-shaped ligatures with mean values close to zero; Group B: Conventional Morelli brackets with used ligatures and means of 44 cN; and Group C: Conventional Morelli brackets with new ligatures and means of 66 cN.

DISCUSSION

The purpose of this study was to compare the magnitude of classical friction among different orthodontic archwire ligation methods, including two Brazilian products recently launched on the market: Easy Clip self-ligating brackets and 8-shaped ligature. 0.014-in Contour NiTi wire and 0.019 x 0.025-in steel wire were tested with the aim of assessing the magnitude of classical friction both in the phase of leveling and in the anterior retraction stage.

When using 0.014-in NiTi wires, the classical friction force produced by new elastomeric ligatures displayed a mean of 64 cN, an intermediate value between those found in other studies, which ranged between 31 and 119 cN.^{1,3,7,20} The 8-shaped ligature and Damon MX, Smart Clip, In-Ovation, Easy Clip and Synergy brackets exhibited friction levels approaching zero, and the differences exhibited by the new elastomeric ligatures were statistically significant, yielding results that corroborate those found in the literature.^{1,4,6,7}

Table 1 - Descriptive analysis and comparisons between classical friction forces (cN) of 0.014-in Contour NiTi wire.

Groups	Brackets	Mean	s.d.	Min.	Max.	≠ sig.*
A	D, EC, IO, SC, S, A8	0,6	0,4	0	1,3	B,C
B	Used ligature	44	17	18	68	A,C
C	New ligature	66	10	49	79	A,B

D: Damon MX; EC: Easy Clip; IO: In-Ovation; SC: SmartClip; S: Synergy; A8: 8-shaped ligature. *p < 0.01

Table 2 - Descriptive analysis and comparisons between classical friction forces (cN) in 0.019 x 0.025-in steel wires.

Groups	Brackets	Mean	s.d.	Min.	Max.	≠ sig.*
D	D, EC, SC, S, A8	0,7	0,5	0,1	1,5	E,F
E	IO	45	11	28	59	D,F
E	Used ligature	49	11	33	65	D,F
F	New ligature	82	15	52	97	D,E

D: Damon MX; EC: Easy Clip; IO: In-Ovation; SC: SmartClip; S: Synergy; A8: 8-shaped ligature. *p < 0.01

In general, tests with round wires tied with elastomeric ligatures displayed a high magnitude of classical friction. Most in vitro studies, however, employ new elastomeric ligatures, which is a limitation since in clinical conditions elastomeric ligatures subjected to stretching are permanently deformed, reducing the contact force between orthodontic wire and bracket.^{16,17} In this study, a statistically significant difference found in the magnitude of classical friction between the new ligatures (64 cN) and the used ligatures subjected to stretching for 36 hours (44 cN) confirmed the relaxing influence of elastomeric ligatures on the reduction of classical friction.

When using 0.019 x 0.025-in steel wire, the brackets with new (unused) ligatures exhibited a mean friction of 82 cN, significantly higher than the value exhibited by the used elastomeric ligature, which reached 49 cN, an outcome that was similar to that recorded for the active In-Ovation brackets, whose mean was 45 cN. The high magnitude of classical friction exhibited by active self-ligating brackets with rectangular 0.019 x 0.025-in wire reinforces the advantage of using space closing loops, which produces a friction-free mechanics.

Moreover, regarding the rectangular 0.019 x 0.025-in wire, Damon, Easy Clip, Smart Clip, Synergy and 8-shaped ligatures showed levels of friction close to zero, with results that were similar to those found by Hain,⁹ Griffiths⁸ and Gandini,⁷ however other investigations found significant friction forces in passive self-ligating brackets with large cross-section archwires.^{2,5,18,19} Such differences are probably related to (a) the number of brackets used in the clinical simulation device and (b) to a misalignment between slot and testing machine. These factors reduce the slack between wire and bracket slot, predisposing to the emergence of binding.

The angle at which the slack between wire and slot disappears, known as critical contact angle, constitutes a milestone in the evaluation of classical friction because it is at this point that the contact force between archwire and bracket slot occurs, thereby producing binding, which is incorporated into the total friction and prevents classical friction from being assessed separately.¹⁹ For this reason, it is important that researches be conducted on the friction produced by the various ligation methods be ensured of the absence of binding during mechanical tests.

The second order critical angle (mesiodistal direction), between a 0.019 x 0.025-in rectangular wire and a 0.022 x 0.028-in slot bracket with a width of 3.5 mm is of approximately 1.5°.¹¹ The greater the bracket width, the lower the second order critical angle, which increases the likelihood of binding¹³ (Fig 8). In classical friction tests where the archwire is made to slide along several brackets, the second order critical angle is even smaller as the width in question corresponds to the distance between the brackets located at the ends. Therefore, even a minor misalignment between wire and slots will produce a contact between wire and bracket slots, as well as binding, which increases the total friction and hampers

the measurement of classical friction separately.¹⁹ Thus, in order to reduce the likelihood of bias caused by binding it is convenient to use only one bracket in tests that assess the magnitude of classical friction.

The method used to insert the wire into the Instron machine is yet another factor that can reduce the slack between the rectangular wire and the slot, thus producing binding. Wire insertion is usually accomplished by means of a latch or a vise. This maneuver, however, can twist the wire and cause third order binding (buccolingual direction).¹³ The third order critical angle between a rectangular 0.019 x 0.025-in wire and a 0.022 x 0.028-in bracket slot is about 87 degrees, a value that reflects the limit of wire rotation upon insertion of such wire in the testing machine.¹³ However, torque also affects the second order critical angle. Rectangular wire torsion increases the effective height of the rectangular wire, decreasing the slack in the slot and further reducing even more the second order critical angle, which raises the likelihood of binding.^{11,13}

In this research, due to technical limitations which made it difficult to achieve absolute alignment between the slot and the rectangular wire attached directly to the vise, it was decided to install between the vise walls a steel tube with the rectangular wire loose in its interior. In this way, the method used to attach the wire to the Instron machine did not interfere with the relationship between archwire and slot, thereby averting rectangular archwire torsion (Fig 7).

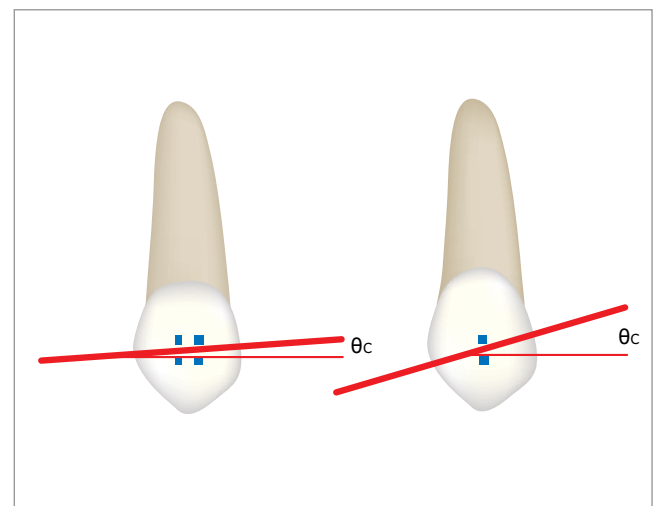


Figure 8 - Influence of bracket on second order critical angle: the greater the bracket width of the bracket, the smaller the second order critical angle (θ_c).

In addition to adopting a methodology to avoid the bias produced by binding it is necessary to verify the effectiveness of such method prior to performing classical friction assessment tests. In this study, such confirmation was achieved by pulling the archwire inside the slot without the use of any ligation system. In this scenario, resistance to sliding was zero. Should there be any resistance to sliding, the cause should be ascribed to binding, since no ligation friction was present.

It is also important to note that although the self-ligating brackets, ligatures and special brackets are equally effective for classical friction control, they are considerably different in other aspects. One advantage attributed to self-ligating brackets is faster seating and removal of orthodontic archwires as well as longer time intervals in between consultations when compared to conventional elastomeric ligatures.^{3,10,14,21} In addition,

self-ligating brackets produce less plaque retention compared to brackets with conventional elastomeric ligatures.¹⁵ Conversely, the advantages of ligatures and special brackets over self-ligating brackets are lower cost and the attractiveness of colorful elastomeric ligatures, which arouse the interest of children and adolescents.

CONCLUSIONS

Damon MX, Easy Clip, Smart Clip, Synergy bracket systems as well as the 8-shaped ligature are equally effective alternatives for controlling classical friction with 0.014-in NiTi wire and 0.019 x 0.025-in steel wire.

In-Ovation brackets proved effective in reducing classical friction with 0.014-in NiTi wire, whereas for the 0.019 x 0.025-in wire it features the same magnitude of classical friction as used conventional elastomeric ligature.

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Nickel-titanium alloys: A systematic review

Marcelo do Amaral Ferreira¹, Marco Antônio Luersen², Paulo César Borges²

Objective: A systematic review on nickel-titanium wires was performed. The strategy was focused on Entrez-PubMed-OLDMEDLINE, Scopus and BioMed Central from 1963 to 2008.

Methods: Papers in English and French describing the behavior of these wires and laboratorial methods to identify crystalline transformation were considered. A total of 29 papers were selected.

Results: Nickel-titanium wires show exceptional features in terms of elasticity and shape memory effects. However, clinical applications request a deeper knowledge of these properties in order to allow the professional to use them in a rational manner. In addition, the necessary information regarding each alloy often does not correspond to the information given by the manufacturer. Many alloys called “superelastic” do not present this effect; they just behave as less stiff alloys, with a larger springback if compared to the stainless steel wires.

Conclusions: Laboratory tests are the only means to observe the real behavior of these materials, including temperature transition range (TTR) and applied tensions. However, it is also possible to determine in which TTR these alloys change the crystalline structure.

Keywords: Nickel-titanium wires. Thermoelasticity. Shape memory alloys. Superelasticity.

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INTRODUCTION

Metallic alloys that tend to return to the original shape after large deflections have been appreciated since the 50s. They have been studied not only for their use in Aeronautical Engineering, because of their sufficient ductility,²² but also in Medicine in the development of prostheses that replace long bones and in the study of surfaces and biofilms.¹⁴ In Orthodontics, these materials are used in archwires for the alignment of teeth, in the initial stages of treatment, when large deflection is necessary and also because they present a low modulus of elasticity (E) and excellent spring-back when compared to other alloys (Fig 1). Table 1 shows the nature of metallic alloys used in Orthodontics and their mechanical properties.

There is great variability in the amount of stored energy in same cross-section nickel-titanium alloys, available from different manufacturers. Many of them are commercialized as shape memory alloys, while others do not even show the effect of superelasticity¹⁷ and present characteristics of martensitic-stabilized alloys as the alloys originally known as Nitinol (Unitek, Monrovia, CA, USA). Some studies^{4,10,11,15,24} question the comparative methods by means of laboratory tests which do not correspond to the variability of clinical situations found.

The aim of this paper is to discuss the behavior of the mechanical properties of these alloys according to literature.

Characteristics and current status of nickel-titanium alloys

Nickel-titanium alloys were initially studied in laboratories by physicists in the beginning of the 60s⁸ and later developed for clinical use.¹ Due to the development of these alloys, new options have emerged such as the nickel-titanium arch wires with superelasticity and thermoelastic properties.

Initially, nickel-titanium wires presented greater flexibility when compared to other alloys, such as stainless steel, cobalt-chromium and titanium-molybdenum alloys (TMA). Nickel-titanium alloys, known by their brand name Nitinol (55% Ni; 45% Ti), are produced through industrial processes that characterize them by stabilized martensite, due to cold work.¹ Effectively, they do not

present the so-called shape memory effect or the superelasticity effect. They just present low modulus of elasticity (E) and large springback, in other words, wires made of these alloys are flexible and show linear behavior (Fig 2).

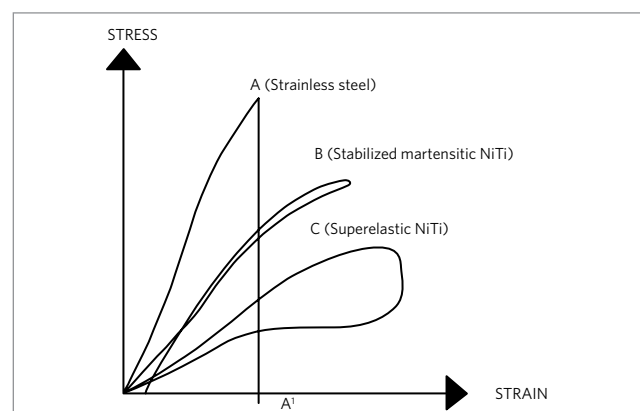


Figure 1 - Stress x Strain diagram. A, B and C wires present different stiffness. A represents stainless steel behavior; B represents stabilized martensitic wire (ex. nitinol) and C represents superelastic wire.

Table 1 - Wire material, Elastic limit (σ_e) and Elasticity modulus (E).

Wire material	Elastic limit (MPa)	Elasticity modulus (E) (GPa)
Stainless steel	1720/1543-1966	193
Titanium molybdenum	1240 1380/769-1254	65-100
Cobalt-chromium	1792	193
Nickel-titanium	1650	33

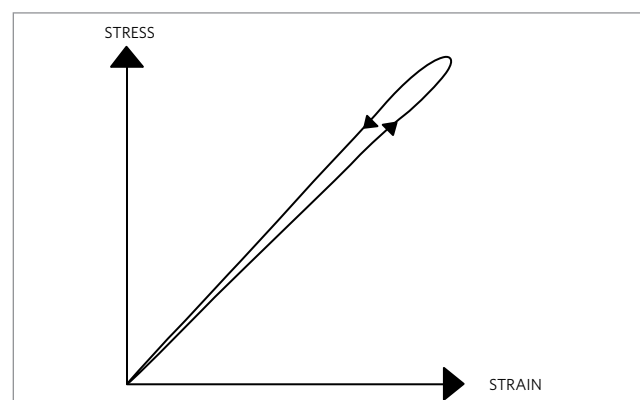


Figure 2 - Stress x strain graph. Analyzing the graph, this could be a martensitic alloy-stabilized, as well as a superelastic alloy, the deformation of which was not sufficient to cause the effect of superelasticity (plateaus). There are superelastic alloys whose A_f is so low that it is useless for clinical use because does not suffer crystal change with the forces commonly used in the daily clinic.

Nowadays, nickel-titanium alloys known as martensitic-stabilized (Nitinol), austenitic active and martensitic active alloys^{10,26} are available. Austenitic active and martensitic active alloys present different rigidity depending on temperature and as show the thermoelastic effect or shape memory. For the martensitic-stabilized alloys, it is expected only good elasticity effect, thus having good springback; however, they can be deformed permanently, if a certain limit is exceeded or due to long time remaining in the mouth (moderate or severe crowding, for example). Superelasticity or shape memory effects should not be expected. Austenitic active alloys should present the effect of superelasticity (also known as pseudoelasticity,²⁶ confirmed by curve with plateaus, which are not possible in martensitic-stabilized alloys). Many NiTi alloys are described as binary, in other words, they are characterized as presenting two phases, one NiTi matrix phase and a precipitation phase Ni_3Ti_4 .¹²

Martensitic alloys are characterized as ductile and plastically deformable, while austenitic alloys are stiffer and not plastically deformable³. In a more simplistic way, it might be stated that austenitic active wires are more flexible and have good springback at room temperature; and if a certain tension (force) is applied upon them, small areas of martensitic crystalline structure might be formed, making them less stiff in these areas and, consequently, easier to fit in a slot. In other words, little islands of crystalline martensitic structure are formed in a predominantly austenitic body. On the other hand, martensitic active wires show, at room temperature, very poor resistance to stress and discrete springback, so that they seem to accept a certain bend and, after removing it, the wire moves discretely toward the original shape, but without success because of the force decay. However, as they receive heat from the mouth, they initiate an austenitic crystalline alteration, becoming more resistant to stress and regaining their initial shape, confirming the shape memory effect. Once the heat is removed or the wire is cooled down, they present their initial characteristic, having predominantly a martensitic crystalline structure. In this alloy exist a mixed or rhombohedral phase "R" at room temperature that coexist with austenite and martensite structure.

MATERIAL AND METHODS

Articles related to the topic were researched (Entrez-PubMed – U.S. National Library of Medicine e BioMed Central) from 1963 to 2008. The words NiTi wires were accessed and 375 occurrences were found. Among these occurrences, we have selected articles that contained information about tension tests, torsion tests, bending tests or other methods for verifying the behavior and crystallography of nickel-titanium alloys. A textbook on Biomedical Engineering was also used as source of information.

DISCUSSION

In graphic terms, the crystalline transformation of the austenitic active nickel-titanium alloys might be demonstrated by a straight line with a certain inclination, indicative of its degree of rigidity (E), which after a certain magnitude of applied bend, goes through a crystalline transformation (molecular arrangement), changing from austenite to martensite, represented by plateau A (Fig 3), indicating that regardless of more wire deformation, the tension is practically the same. In other words, the tension is constant along the resulting deformation. After the tension is removed (for each tension applied there is a corresponding force), the curve shows a decrease at its tension magnitude, with a new inclination and, consequently, new rigidity, until a new plateau B is formed, though at a smaller tension magnitude.

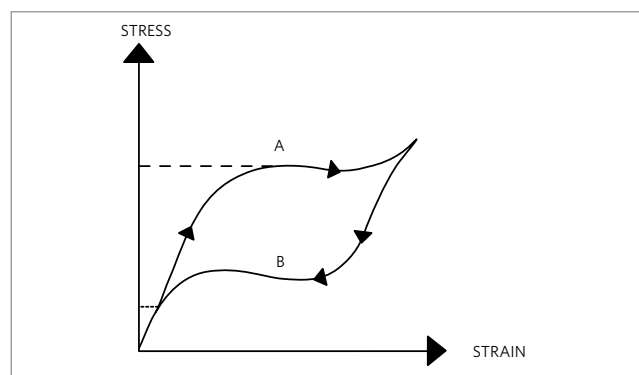


Figure 3 - Stress x strain graph. Typical curve for a superelastic alloy, forming plateaus. The plateau A represents the crystalline martensitic change at a certain level of tension, while plateau B represents a new martensitic transformation, but at a lower voltage level. Between A and B there is new formation of austenite with stiffness equal to that prior to the plateau A. The plateau A is formed due to the stress-induced martensite, due to metal arc be attached to the slot brackets, while the plateau B is formed due to the reduction of tension (motion toward the dental arch alignment).

The difference between the plateaus is explained by the phenomenon of hysteresis (loss of energy because of crystalline alteration). After the tension is removed, reverse crystalline transformation from martensite to austenite occurs. This graph describes the superelasticity effect, not observed regarding the martensitic-stabilized alloys, such as Nitinol.

The effect of superelasticity introduces a new property of metallic alloys, characterized by the appearance of martensitic crystalline structures in an austenitic structure, after the use of a certain stress. This generates areas of stress-induced martensite (SIM) which takes place in the parts of the metallic wire tied to the brackets of the most unaligned teeth; however, as the teeth get aligned, these areas of induced martensite disappear and are replaced by austenite, since the induced martensite areas are very unstable. Depending on the manufacturer, the nickel-titanium wires have a temperature range in which it is possible to observe the effects of crystalline alteration. This range of temperature is known as transition temperature range (TTR) and it presents final and initial limits, denominated – for the austenitic crystalline structure – as final austenite (Af) and initial austenite (As); thus, in Af temperature the maximum elasticity of these alloys takes place, while in As temperature weak elasticity is observed. For the martensitic active alloys there is also a temperature range in which these phenomena take place; thus, Mf and Ms indicate a higher level of martensite and lower level of martensite, respectively. Many of these wires are sensitive to applied tension and to temperature. Focus is on the concept of crystalline TTR, the temperature range in which some crystalline transformation might take place, and the austenitic final temperature was defined (Af), in which the alloy reveals a high stiffness phase, as well as the final martensitic temperature (Mf), in which the alloy reveals a low stiffness phase.

Figure 4 shows the characteristic curve of shape memory for the wires, Ms and Mf represent the temperatures where crystallographic martensitic alteration begins and where it ends, respectively. On the other hand, As and Af temperatures represent where the austenitic alteration begins and

ends, respectively. Therefore, there is martensitic transformation between Ms and Mf temperatures and the wire might present characteristics of plasticity; on the way to As temperature, the wire begins to show greater rigidity. It might be stated that superelastic wires may return to the initial shape when a force is abruptly applied and when a force of considerable magnitude is removed. In the martensitic stage, two effects are noticed: In the first one, after some initial deformation, the crystallographic variants that might be found in 24 shapes of coexisting martensite and after the removal of force, these variants reorganize themselves in their initial positions and the wire returns to its original shape. In the second case, the nickel-titanium wire shaped in the austenitic state is cooled down until it reaches the martensitic state. If during the process the material is deformed, it returns to its initial shape after heating and this phenomenon is called shape memory effect.¹⁶ Austenitic structures are face-centred cubic α phase while martensitic structures correspond to body-centred cubic β phase. They have exactly the same chemical constitution, but because of their different crystallographic structure, they do not exhibit the same mechanical behavior.² Between iM and fA there are initial levels of each transformation where the alloys begin to show some crystalline transformation. The highest temperature in which it is still possible to find the formation of martensite is called Md.¹⁹

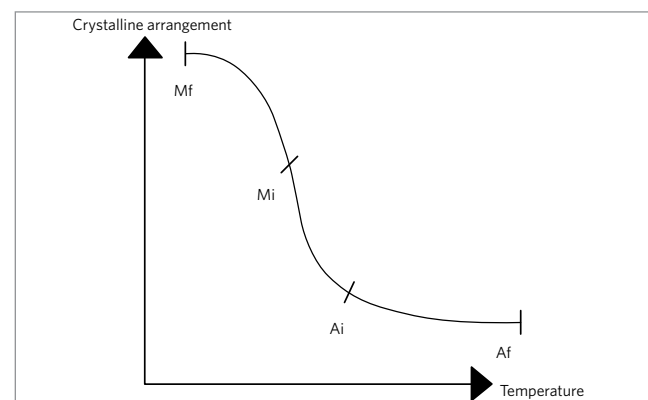


Figure 4 - Austenitic-martensitic transformation of crystalline arrangement vs. temperature.

Table 2 - Reviewed literature, authors, wire material and applied tests.

Authors	NiTi nature	Test / Method
Nakano et al ²⁴	Superelastic NiTi wires with different cross-sections	Three point bending test
Augereau et al ²	Shape memory NiTi (Cu-Zn-Al)	Echography and acoustic microscopy
Parvizi, Rock ²⁵	Superelastic NiTi 0.40 mm and 0.40 x 0.56 mm	Three point bending tests (20°C, 30°C and 40°C)
Santoro, Beshers ²⁷	Thermoelastic and superelastic NiTi wires 0.017 x 0.025-in	Three point bending tests
Buehler, Gilfrich, Wiley ⁸	NiTi wires	X-ray diffraction (XRD), tension tests, compression tests
Andreasen, Hilleman ¹	NiTi Wires - stoichiometric composition	X-ray diffraction, tension tests, compression tests
Uchil ²⁸	Nitinol cold-worked 40% wire sections of 6 cm	Dilatometric measurements and electrical resistivity
Burstone, Quin, Norton ⁹	Chinese NiTi (superelastic) 0.016-in	Torsion tests
Miura et al ²¹	Japanese NiTi (superelastic)	Three point bending tests
Gurgel et al ¹⁵	Superelastic NiTi wires 0.017 x 0.025-in	Torsion tests
Filleul, Constant ¹¹	NiTi (superelastic) 0.017 x 0.025-in	Torsion tests and differential scanning calorimetry (DSC)
Bradley ⁵	NiTi wires (superelastic)	Differential scanning calorimetry (DSC)
Brantley et al ⁶	NiTi wires (0.016-in, 0.016 x 0.022-in and 0.018-in) superelastic and shape memory	Differential scanning calorimetry (DSC)
Brantley et al ⁷	Copper NiTi (35°C), 0.016 x 0.022-in	Differential scanning calorimetry (DSC) and temperature modulated differential scanning calorimetry (TMDSC)
Iijima et al ¹⁷	Copper NiTi (35°C), Neo-Sentalloy and Nitinol SE 0.016 X 0.022-in	Torsion tests X-ray diffraction (XRD)
Filleul, Bourgoin ¹⁰	SS, CoCr, NiCr, Titanium-molybdenum and Nitinol wires	Torsion tests
Fischer-Brandies ¹²	Superelastic NiTi wires: 0.016 x 0.022-in, 0.017 x 0.025-in, 0.018 x 0.025-in	Bending tests (22°C, 37°C and 60°C)
Meling, Ødegaard ¹⁸	Superelastic NiTi wires, Nitinol and titanium-molibdenum wires: 0.016 x 0.022-in, 0.017 x 0.025-in and 0.018 x 0.025-in	Torsion tests (25° torsion angle at 37°C)
Meling, Ødegaard ¹⁹	Superelastic NiTi wires (0.017 x 0.025-in and 0.018 x 0.025-in)	Torsion tests (25° torsion angle) at 18°C, 27°C, 37°C and 40°C
Meling, Ødegaard ²⁰	Superelastic NiTi wires (0.018 x 0.025-in) and thermoelastic wires (Copper NiTi 0.017 x 0.025-in)	Torsion tests at 20° (10°C to 80°C)
Barwart et al ⁴	NiTi Japanese coils (50 g, 100 g, 150 g and 200 g)	Differential scanning calorimetry (DSC)
Somsen et al ³⁰	NiTi (51% < x < 54%)	Thermal control, electrical resistivity, X-ray diffraction
Bartzela et al ³	Thermoelastic NiTi wires 0.016-in, 0.016 x 0.022-in, 0.017 x 0.025-in and 0.018 x 0.025-in	Three point bending tests
Garrek, Jordan ¹³	Superelastic NiTi wires (0.016 x 0.016-in, 0.018 x 0.018-in and 0.020 x 0.020-in)	Three point bending tests at 37°C ± 5°C
Schneevoigt et al ²⁹	NiTi coils (different geometries)	Compression tests (27°C, 37°C and 47°C) Applied (0,5 N to 3,5 N)
Muraviev et al ²³	Superelastic NiTi wires (0.014-in, 0.016-in, 0.018-in and 0.020-in)	Mathematical model (large deflections)

Martensite normally forms at the M_s (martensite start) temperature but can form prematurely above the M_s temperature if stress is present. Below the M_s temperature, deformation occurs by martensitic twinning. Between the M_s temperature and the austenite final A_f temperature, the martensite is stress-induced but once induced is stable.¹⁹ Above the M_d temperature, the deformation is due to slip, because martensite can no longer be stress induced.¹⁹ Table 2 shows the variety of studies developed according to the type of test.

To the effect of crystalline transition within a certain temperature range take place at A_f temperature (final austenitic), representing the highest level of occurrence of this crystalline structure, the alloy should be manufactured to respond with good springback for a temperature lower than that of the mouth (e.g. around 27°C), but if it is manufactured to have an A_f of, for instance, 10°C, the alloy will be predominantly austenitic at 10°C; thus, if exposed to a 37°C temperature, the wire would not be useful, considering that the 37°C – 10°C range is large and the wire would be too stiff working as a stiff elastic wire, without presenting the effect of superelasticity or, in other words, pseudoelasticity. Moreover, greater stress would be necessary to induce or keep stress induced martensite (SIM) for a longer period in order to produce a prolonged dental movement. It because there is a greater chance to find austenite in the temperature mentioned in the example given. In addition, stress induced martensite (SIM) is highly unstable. However, if produced to have an A_f of 27°C, the gradient would be 37°C – 27°C, therefore, islands of unstable martensite would be present and the wire would show superelasticity.²⁵ Concerning a wire produced for an A_f of 35°C, the gradient would be so small that this wire would be recommended for use in adults, because the level of austenite would be weak, or in other words, austenite and martensite stages would coexist. In addition, there is evidence that SIM may alter the crystalline transformation temperature towards higher temperatures, making the return to an austenitic crystalline structure difficult.^{16,27} The temperature gradient will, therefore, modulate the crystalline transformation. Thus, if we confront an arch with a certain A_f temperature, the difference between

the temperature specified for the arch and the temperature of the buccal cavity is the gradient, and it will determine the degree of transformation.^{26,27} In this way, the arches available as thermoelastic, with TTR (A_f) 40°C, will be less austenitic in their crystalline structure than those with TTR (A_f) 27°C, due to a higher gradient in relation to the temperature of the buccal cavity (37°C), as exemplified. Arches with higher crystalline TTR have been provided to be used in patients who had a history of periodontal problems because the arches would effectively act only when the patient eat some hot food.

It is necessary to know if the discussed arch presents enough resilience to take the springback to the expected torsional moment during unloading, that is to say, if this arch presents the second plateau at force levels that are not so low, preferably close to the first plateau, meaning lower hysteresis. In other words, it would be important to have an arch that allowed us to obtain martensitic transformation with little stress, and later, due to buccal temperature, the arch would go through austenitic transformation, and that would help the unloading of the torsional moment to take place in a more profitable way, but without much hysteresis (loss of energy due to crystalline alteration). Arches with “higher temperature” will not be effective for the effect of torsional moment; consequently, it would be preferable to choose arches with crystalline TTR from 22°C to 27°C. Stress might interfere upon the mechanical properties of the alloy, as well as upon the TTR, i.e., it might increase the A_f of an alloy, or decrease it. Resistivity tests²⁷ show that the curve of resistivity gets flatter, indicating that crystalline alteration decreases from one stage to another. The more an elastic alloy is bent to fit in the slot, more A_f is increased, consequently a higher temperature will be necessary for superelasticity to take place; higher temperature will be necessary to undo the martensite islands formed during the bending of the wire, and for the alloy to guide the tooth to the end of the elastic work of the arch, meaning that a higher temperature will be needed for the conversion of martensite into austenite (the alloy cannot regain its austenitic stage).

Studies⁴ about the TTR of nickel-titanium Japanese NiTi closed coil springs (Sentallloy, GAC

International, Bohemia, USA), with different force magnitudes (50 g, 100 g, 150 g and 200 g) using differential scanning calorimetry technique (DSC) have concluded that the springs became superelastic when the temperature increased and would no longer be superelastic when the temperature decreased at M_f . Both M_f and A_s temperatures were below buccal temperature. At room temperature and some degrees below the tested springs showed the superelasticity effect, and that would fit the purposes of orthodontic use, even when considering the alterations of buccal cavity temperature, such as during meals. In this way, for the superelasticity effect to become useful in orthodontics, the transitional crystalline alterations (martensitic-austenitic or austenitic-martensitic), must take place at temperature a little below the mouth temperature.

Sentalloy alloys present a transitional temperature that varies from 8°C (A_s) to 28°C (A_f) at maximum stress, but when buccal temperature is 36°C or 37°C , they just show the austenitic stage, unless the temperature drops below 28°C . On the other hand, Copper NiTi 35°C alloys (Ormco, Orange, CA, USA) are superelastic at 35°C (A_f) and only below 7°C (A_s) turn to martensitic; however, with induced stress, the TTR stands between 23°C (A_s) and 41°C (A_f); consequently, when the temperature is below 23°C , only the conventional elastic effect takes place, making the alloy return force not meaningful²⁷. Figure 5A shows a clinical situation where the nickel-titanium arch does not allow total

contact with the bracket slot, meaning that the plateau could not be reached; consequently, it would not be working as superelastic, or it was not possible with such stress to produce crystalline alteration with the formation of martensite in that wire. On the other hand, in situation B (Fig 5B), the arch could fit the slot completely, presumably reaching the plateau, once this wire allowed the crystalline martensitic transformation to take place with the same stress. If the wire is forced into the bracket, as in situation A, stress induced martensite is being produced at a very high force level, which not only is not interesting for clinical application, but also might plastically deform the wire, and consequently the mechanical properties of the alloy, the TTR change and the correspondence between this temperature and the buccal temperature range is lost. Thus, a stage of transformation of austenite into martensite, or vice versa, might be altered and the alloy will not express its characteristics and will behave only as a resilient alloy, elastic with a lower elasticity model. In this way, a clinician might purchase an expensive alloy, without effectively using properties. The alloy will not be able to move the tooth effectively, in other words, the alloy will not reach its final transition temperature (A_f) because it was poorly chosen for that clinical situation.

Since the first studies⁸ about nickel-titanium alloys were introduced, the alloy have improved in mechanical properties in order to respond to clinical needs, but laboratory studies have shown that

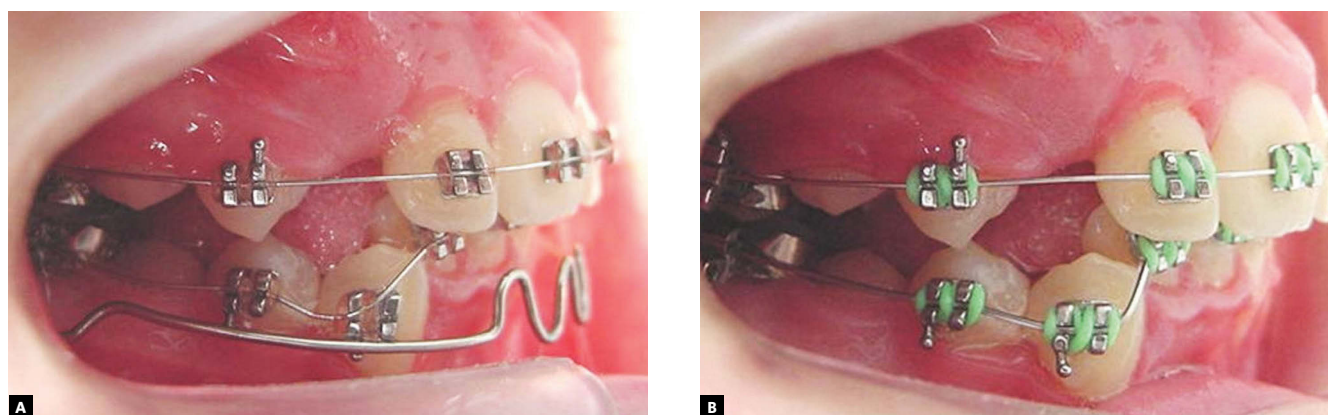


Figure 5 - A) Clinical situation where is not possible to insert a NiTi wire into the bracket slot. This situation can occur when superelastic wires can not reach a plateau, i.e. impossible to produce SIM in clinical levels. **B)** In this situation SIM formed and the wire could be fitted into the slot bracket.

there is a lack of characterization of these products. Manufacturers commonly do not specify the real characteristic of the arches.

A lack of reproducibility of the description of properties has been observed. Therefore, many arches available as superelastic do not behave as, others show a very high TTR in which there is crystalline alteration, from the stage where the alloy is totally martensitic until the stage where it is totally austenitic, so that they do not reveal a meaningful effect in the buccal cavity. That happens due to the little difference in temperature between the buccal cavity and the final austenitic temperature of the alloy (temperature gradient) or due to the fact that the wires commercialized present transition temperatures calculated for unstressed situations, consequently not simulating several stress applied situations, such as constant stress conditions in cases of misalignment because of lack of space.

Studies¹¹ have shown that at higher the temperature, more difficult it will be for the arches to reach stress induced martensite through applied tension. There are arches whose transition temperature is negative; thus, even before being placed in the mouth, they already show a certain rigidity, so it will be more difficult to insert them totally in the bracket slot, that is, the arches do not reach the martensitic structure, do not form a plateau and an absurd amount of tension would be required, clinically not common, to produce SIM. Arches with such behavior cannot be called superelastic (Fig 1).

Researches developed through the calorimetry technique, by means of temperature modulated differential scanning (MDS), have shown that the stages of transformation of Copper 35°C NiTi alloys (Ormco, Orange, CA-USA) require an intermediate R stage; besides, oxide precipitate and density differences are due to the reaction of nickel-titanium with residual oxygen found in the environment.⁶

The literature shows that the classification and understanding of the properties of these alloys become confusing due to the complexity of these phenomena and only studies based on research are capable of determining real effects. Commercially, these alloys are described in a very simplistic way considering their advantages. Researches show that these materials present complex behavior and

cannot be examined in an isolated manner.

The first alloy used in Orthodontics, known commercially as Nitinol, did not have the effects of superelasticity, only a discrete shape memory effect, with low rigidity, due to its manufacturing process which produced an alloy with mechanical hardening characteristics (cold work machining that increases the size of grains, altering then the mechanical properties of the material). That is verified by the fact that after removing the arch, after a certain period of use, it was plastically deformed (martensite-stabilized in a passive way), if alignment was more severe, these alloys were characterized as being martensite-stabilized and had a very discrete shape memory effect, with temperature increase.

The metallic alloys, in general, might also be studied by examining metal phase transformation diagrams, which reveal the microstructure of the alloys and, as a result, how they will behave concerning their physical properties. Other methods, such as X-rays diffraction (XRD), which allows the study of several crystallographic forms of nickel-titanium³¹ alloys, the differential scanning calorimetry (DSC)^{5,6} technique and the most recent known as temperature modulated differential scanning calorimetry (TMDSC), are effective means to access the stage transformations that are generated after applying tension or torsion upon these alloys; however, diffraction by X-ray reveals itself as more limited for penetrating less than 50%.⁷

Research¹⁷ using nickel-titanium alloys by means of X-ray diffraction (XRD), with transformation stages at low temperature varying from -110°C to 25°C, was compared to the results of previous studies⁷ performed using the TMDSC technique. For the study, alloys commercially known as Copper NiTi 35°C (Ormco, Orange, CA, USA), Neo Sentalloy (Sentalloy, GAC International, Bohemia, USA) and Nitinol SE (3M Unitek, Monrovia, CA, USA) with transversal section of 0.016 x 0.022-in were selected. All the samples studied were superelastic, although the Neo Sentalloy (GAC International), samples are commercialized as having shape memory. A more complete study should take into consideration the complementarity of techniques such as XRD, TMDSC and TEM (transmission electronic microscopy). X-ray diffraction

(XRD) shows peaks characteristic of the martensitic transformation technique. Thus, non-superelastic alloys are austenitic at room temperature, and that denotes that the martensitic stage is found at very low temperatures.⁷

A study² was performed with shape memory alloys (Cu-Zn-Al) by means of echography and acoustic microscopy in order to observe the crystalline changes in the grain structures step by step. The structures of these alloys (38,5% Zn face crystalline transformation at temperature close to room temperature) have the same chemical constitution, but different crystallographic structure. Martensitic and austenitic structures are cubic of centered body (phase β) and cubic of centered face (phase α), respectively, and that explains the fact that they do not show the same mechanical behavior. Martensitic structures reveal themselves to be as straight slip bands inside the austenite grains, while austenitic structures show grains with different shades of gray.

A study²⁸ performed by means of DSC and electrical resistivity to crystalline transformation in two stages, NiTi and NiTiCu (300°C to 800°C) alloys, found that the R stage is suppressed in NiTi-Cu alloys due to the addition of copper, while NiTi alloys present this intermediate stage from 340°C to 410°C; however, above 410°C there was no production of R stage.

The effect of superelasticity was observed in nickel-titanium arches through tension (axial) and stress tests.²¹ Nickel-titanium arches (Chinese NiTi, GAC International, Bohemia, USA) tested by means of stress tests to determine the rigidity, springback and the maximum force of stress, for large activations, showed rigidity of about 7% compared to the one found in stainless steel, while in activations of little amplitude, rigidity was 28% in relation to stainless steel. These alloys showed excellent springback capacity, and they might be stressed 1.6 times more than nickel-titanium Nitinol SE (3M, Unitek, Monrovia, CA, USA) alloys. They show a transition temperature a little below mouth temperature, but they are austenitic in this temperature, so they do not reveal effectively the thermoelastic effect, while allowing the production of stress induced martensite.

In three point stress tests with 42 samples of

NiTi alloys of 0.016-in and 0.016 x 0.022-in, which were produced by 9 different manufacturers, we noticed that there was a difference among the samples concerning the stored load with the same transversal section.²⁴

The behavior of crystalline transformations, and chemical and topographical compositions of the surfaces of NiTi alloys of different commercial brands, in the shape of rectangular wires (0.016 x 0.022-in.) such as Neo Sentalloy F80 (Sentalloy, GAC International, Bohemia, USA), Thermo-Active Copper NiTi (A-Company, San Diego, CA, USA; Ormco, Orange, CA, USA), Rematitan LITE (Rematitan 'Lite' nickel titanium, Dentauro, Germany), Titanol SE S (Forestadent Bernhard Förster GmbH, Germany) and Titanal (Lancer Orthodontics Corporation, USA), showed that besides the austenitic and martensitic stages there is a stage called R phase. The tests were performed within different temperatures (22°C, 37°C and 60°C). The chemical composition and surface analysis tests were performed by means of X-ray spectroscopy, through a scanner attached to an electronic microscope. Regarding the different temperatures analyzed, differential scanning calorimetry (DSC) was used, varying from -80°C to +80°C. The mechanical properties were analyzed through three point stress tests. The stress tests showed plateaus during the loading and unloading of tensions.¹²

In recent research^{19,20} the rigidity of nickel-titanium wires during activation and deactivation was observed. It was concluded that if a superelastic alloy is submitted to cold water during its activation phase, the stress force drops and remains at a sub-baseline level until it is once again heated (transient effect). On the other hand, if the alloy is rapidly cooled, during deactivation, the force drops temporarily and the sudden heating induces a transitory increase in the rigidity of the alloy during activation, but with prolonged effect, when heated, during springback (deactivation). The higher the degree of activation (tension) used for activation (dislocation), more springback will become possible during the deactivation phase. The amount of stress required to induce the production of martensite increases as temperature increases from Ms (initial martensite) to Md temperature (maximum

temperature where martensite might still be found), in other words, the higher is the tension (stress) applied, the higher the temperature, so that austenitic transformation becomes possible.²⁰

Three point stress tests with NiTi thermoelastic alloys have shown great variability, qualitative and quantitative, performance, since many alloys have remained deformed after the test, and others showed weak or no superelasticity. A study³ that involved 48 thermoelastic alloys of transversal sections 0.016-in, 0.016 x 0.022-in, 0.017 x 0.025-in and 0.018 x 0.025-in classified them as true superelastic when the plateau showed deflection $\geq 0,5$ mm; superelastic borderline when the plateau showed deflection $< 0,5$ mm and $> 0,05$ mm and non-superelastic when the plateau showed deflection $\leq 0,05$ mm.

The rigidity effect of nickel-titanium alloys was studied concerning the transversal section. Thus, superelastic alloys were used (Ortho-Force, France) with square transversal sections (0.016 x 0.016-in, 0.018 x 0.018-in, and 0.020 x 0.020-in). The Modulus of Elasticity (E) seems to vary according to the transversal section, but it depends on the amount of martensitic transformation which took place during the phase transformation. An alloy of larger transversal section will not necessarily produce higher forces, meaning that rigidity during stress is not directly related to the transversal section when the superelasticity process takes place.¹³

Torsion tests using superelastic and thermoelastic alloys, aiming to understand the behavior of alloys under thermal variations and according to different degrees of torsion, have shown that the alloys could not respond to temperature variation and remain at a sub-threshold level when there was a change from a high to a low temperature and then back to a high temperature. They could not regain their resistance to torsion. In some tests (temperature varying from 10°C to 80°C) there was a simulation of the thermal changes that take place in the buccal cavity after the ingestion of food. In other torsion tests (25°) superelastic alloys at 18°C, 27°C, 37°C and 40°C did not show martensitic change, but showed plateaus only in 45° and 60° torsions, which would not produce torsion on incisors, since the advocated torsion ranges from 7° to 22°.¹⁸

In another study¹⁹ involving NiTi superelastic

alloys compared to conventional ones and to β -titanium alloys 0.016 x 0.022-in, 0.017 x 0.025-in and 0.018 x 0.025-in sections and 25° torsion at 37°C, it was found a variation in torsion resistance among different alloys and among different manufacturers, and only one alloy tended to superelasticity.

The effect of torsion upon metallic wires of 0.017 x 0.025-in and 0.018 x 0.025-in transversal sections of different types of alloys commonly used in orthodontics, was studied by means of a device that simulated a dental arch. The wires were inserted in the brackets of a patient simulator. At 15° activation, Tru-Chrome Stainless Steel 0.017 x 0.025-in wires (RMO, Denver, CO, USA) restored a torsion 4 times stronger than that of a Nitinol SE 0.017 x 0.025-in wire (3M Unitek, Monrovia, CA, USA).¹⁰

Torsion effects have also been examined in laboratory tests aiming evaluate the rigidity of nickel-titanium alloys. Torsion tests have shown that some samples presented curves without plateaus, and that represents lower energy stored due to differences between martensitic transformation temperatures and those simulating buccal cavity¹⁵ temperatures.

Copper enriched nickel-titanium alloys have shown a decrease in their rigidity and hysteresis, and that would produce a lower moment necessary for activation. However, during deactivation, these alloys could not totally produce the necessary torsion. This paper has demonstrated that in order to select an appropriate superelastic alloy, consideration should be taken not only in the transition temperature, but also rigidity; nevertheless, there is variation between rigidity levels, according to manufacturers and some alloys reveal torsion moments comparable to those of conventional nickel-titanium alloys.

Torsion tests have shown that orthodontic wires whose martensitic phase begins at very low (negative) temperatures depend on a higher unloading torsional moment to form the plateau. In this way, these plateaus would never be reached and, consequently, the wire would behave as a stainless steel wire and the only advantage would be showing a lower modulus of elasticity (E); however, the wire would not reveal any characteristic of superelasticity (formation of plateaus). It has been noticed that the superelasticity effect is influenced by the chemical composition of the nickel-titanium wire (e.g. Ni

content) as well as by room temperature; thus, if Ni content is higher, there will be a decrease in temperature for initial martensitic transformation, and a higher force moment would be necessary to induce martensite, meaning that martensite already begins at low temperatures. As a result, at a higher room temperature, there would already be austenitic transformation and greater applied tension would be necessary to produce SIM transformation.¹¹

Somsen et al³⁰ studied the effect of thermal treatment on the formation of R phase, in Ni-rich NiTi alloys, which is related to Ni_4Ti_3 precipitates. The effect of electrical resistance in NiTi ($51\% < x < 54.5\%$) alloys, $\text{Ni}_x\text{Ti}_{100-x}$, cooled at several temperatures (T_A) and at room temperature, was studied and it was noticed that when the alloys were cooled, at a B2 phase ($T_A=1273\text{K}$) of alloys with $51\% < \text{Ti} < 54\%$, there was an increase in the resistance and there was a decrease below 300 K. Subsequent tempering thermal treatment at 653 K (1h) and cooling cause the anomalous reduction of electrical resistance below 320 K and the occurrence of martensitic transformation from B2 to R phase with $T_R=310\text{K}$, independent of x. On the other hand, after 723 K and 823 K tempering, for 1 hour, there was martensitic transformation in two stages, from B2 to R and subsequently B19' (Ms dependent on x and T_A). After tempering at 923 K or above, martensitic transition could no longer be found. The first stage, at 500 K, shows structural changes inducing martensitic phases at low temperatures. The second stage, at 900 K, shows the formation of phase B2 and the disappearance of other phases, causing martensitic transition. Thus, NiTi alloys reveal great dependence on instituted thermal treatment as well as on their composition. As a result, they show one or two stages of martensitic transformation, the first stage related to moving from phase B2 to B19' (monoclinic) and the second stage of martensitic transformation from B2 to R and later to B19'. The R phase is a rhombohedral distortion of the crystalline structure of the B2 towards $(111)_A$.

Compression tests using Instron machine were performed in order to examine the behavior of nickel-titanium coil springs with different geometrical characteristics. The springs were studied at different temperatures (27°C, 37°C and 47°C) and at compression levels varying from 0.5 N to 3.5 N. The influence of sterilization upon the behavior of 0.016 x 0.022-in cross-section wire was examined and the result obtained was that the width of the superelasticity plateaus of different springs moved from 0% to 66% of relative compression. The higher is the temperature, the lower is the plateau hysteresis. The temperature increase from 27°C to 47°C, caused an increase in the height and a shortening in the width of the plateaus. There was no meaningful influence of the process of sterilization upon the behavior of springs. In this way, different behavior standards have been established for the different spring configurations.²⁹

CONCLUSIONS

- Nickel-titanium alloys have shown a growing evolution, from the first samples with distinctive martensitic characteristics until the current ones, with thermoelastic and superelastic (pseudoelastic) properties.
- Many nickel-titanium alloys available as superelastic do not correspond to manufacture's specifications being just less stiff than stainless steel alloys.
- The ideal alloy would be one that presented a TTR which coincided with or which would be really close to the temperature of the buccal cavity (Af) in order to allow SIM to be formed; one which did not show a shift of TTR because of the stress applied and would have good springback at room temperature; and which showed a small difference between the plateaus (little hysteresis) and the magnitude between the plateaus would be within tension levels compatible with biological dental movement.

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Evaluation of the mechanical behaviour of different devices for canine retraction

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Objective: To mechanically evaluate different systems used for canine retraction.

Methods: Three different methods for partial canine retraction were evaluated: retraction with elastic chain directly attached to bracket; elastic chain connected to bracket hook and with sliding jig activated with the aid of an elastic chain attached to a mini-implant. For this evaluation, a Typodont was adapted to simulate the desired movements when exposed to a heat source. After obtaining the measurements of the movements, statistical analysis was performed.

Results: The mini-implant/sliding jig system (Groups M 0.018-in and M 0.019 x 0.026-in) favored less extrusion and distal inclination of the canines in the retraction stage ($p < 0.005$). Meanwhile, the retraction system with elastic chain directly attached to the orthodontic brackets (Groups C 0.018-in and 0.019 x 0.026-in) favored greater inclination and extrusion than the others, followed by the system of elastic chain attached to the hook (Groups G 0.018-in and 0.019 x 0.026-in).

Conclusions: Canine retraction with the mini-implant/sliding jig system showed the best mechanical control. The worst results were observed with a 0.018 archwire when the elastic chain was attached to the bracket.

Keywords: Corrective Orthodontics. Canine tooth. Malocclusion.

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INTRODUCTION

During orthodontic treatment, precise diagnosis and consequent correct treatment plan presents a high degree of difficulty and complexity.

When defining the treatment plan, a significant percentage of malocclusions, such as discrepancies between tooth and maxillary sizes, and discrepancies between the bone bases normally results in extraction therapies.^{6,5}

Space closure must be performed in a planned and adequate manner.⁷ For this purpose, according to orthodontic planning, the canine teeth will be partially or completely retracted, and afterwards, the remaining spaces will be closed by means of a specific system of force.¹

The choice of the mechanism for canine retraction requires profound knowledge of the characteristics presented by these devices, such as: maximum tooth movement, control of vertical, horizontal and rotational forces, conserving the integrity of the root and circumjacent tissues.^{2,3,4,7,8}

Based on this premise, the aim of this study was to perform a mechanical evaluation of the different systems used for canine retraction, thus making it possible to explain to the orthodontist which would be the best system to develop this function.

MATERIAL AND METHODS

To conduct the experiment, a wax Typodont was mounted in normal occlusion to allow tooth movement when exposed to a heat source.

Once the Typodont was adapted, the teeth were mounted in a Class I malocclusion with bimaxillary protrusion. This malocclusion was selected because extraction of the first premolars is the therapy routinely used in these cases, followed by retraction of the canines and incisors.

After the Typodont was mounted, orthodontic brackets were bonded according to the edgewise slot 0.022 x 0.030-in technique, which would serve as support for the application of orthodontic mechanics.

After the orthodontic appliance was mounted, the Typodont was fixed on a rigid rod, which enabled the occlusal plane to remain parallel to the ground and perpendicular to a 30 cm long ruler, the purpose of which was to measure the extrusion of the incisors that would occur during retraction (Fig 1).

Three different methods of partial canine retraction were evaluated in two different types of orthodontic arches, therefore the groups were divided as follows:

Group C 0.018-in: Retraction performed with elastic chain directly connected to the bracket in a 0.018-in stainless steel archwire (Fig 2).

Group G 0.018-in: Retraction performed with elastic chain connected to the bracket hook in a 0.018-in stainless steel archwire (Fig 3).

Group M 0.018-in: Retraction performed with a sliding jig activated with elastic chain attached to a mini-implant in a 0.018-in stainless steel archwire (Fig 4).

Group C 0.019 x 0.026-in: Retraction performed with elastic chain directly connected to the bracket in a 0.019 x 0.026-in stainless steel archwire.

Group G 0.019 x 0.026-in: Retraction performed with elastic chain connected to the bracket hook in a 0.019 x 0.026-in stainless steel archwire.

Group M 0.019 x 0.026-in: Retraction performed with a sliding jig activated with elastic chain attached to a mini-implant in a 0.019 x 0.026-in stainless steel archwire.

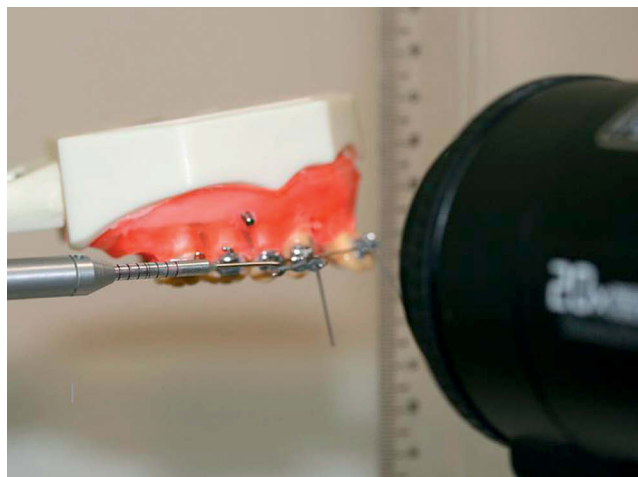


Figure 1 - Typodont in position during the canine retraction assay.

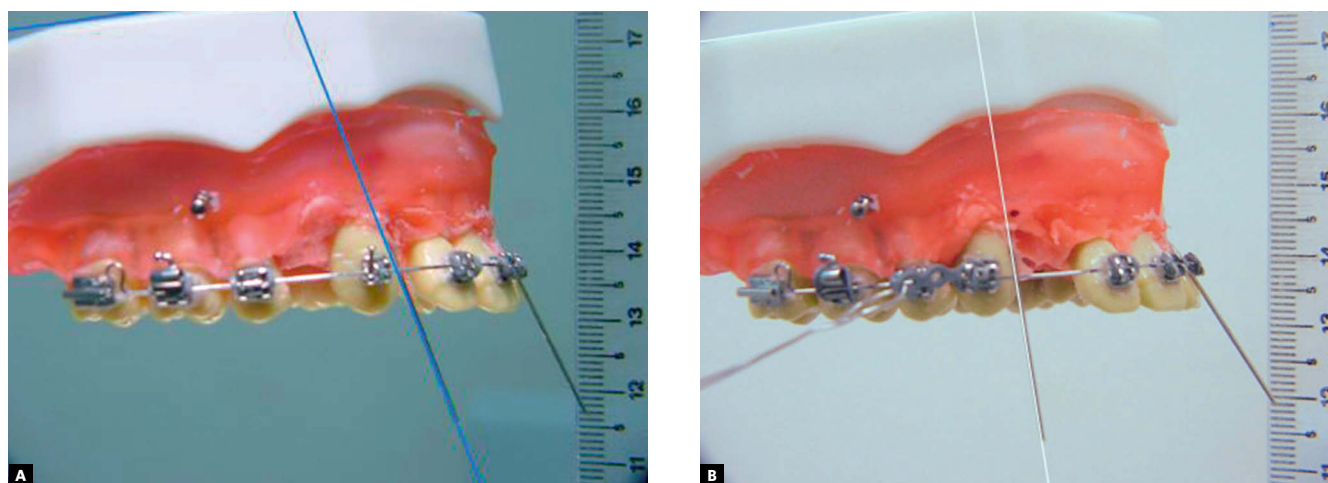


Figure 2 - A) Canine position before retraction with elastic placed on bracket wing; **B)** retracted canine.

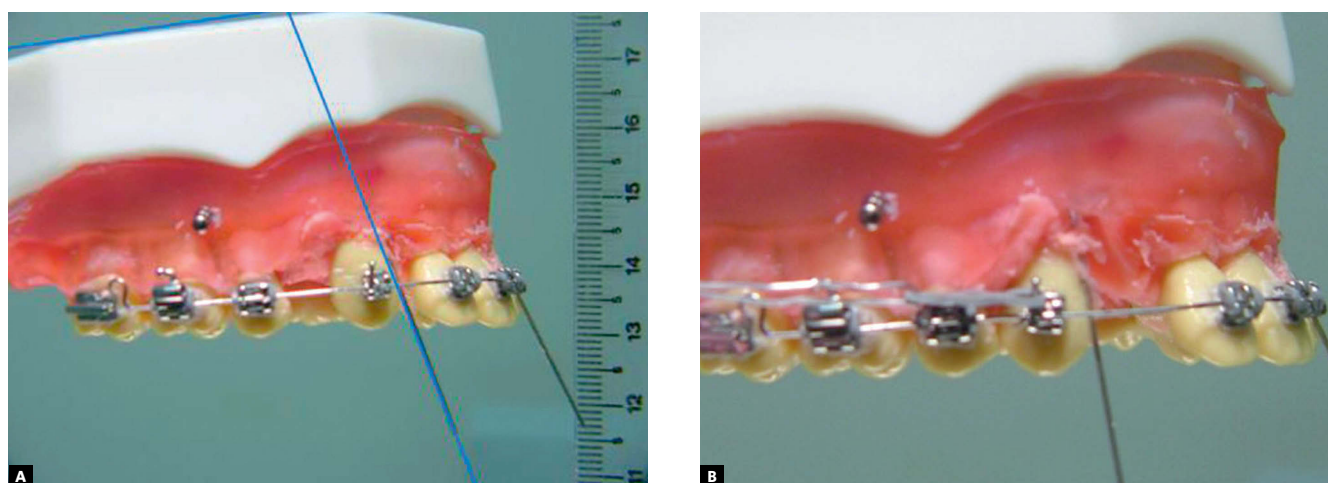


Figure 3 - A) Canine position before retraction with elastic placed on welded hook; **B)** retracted canine.

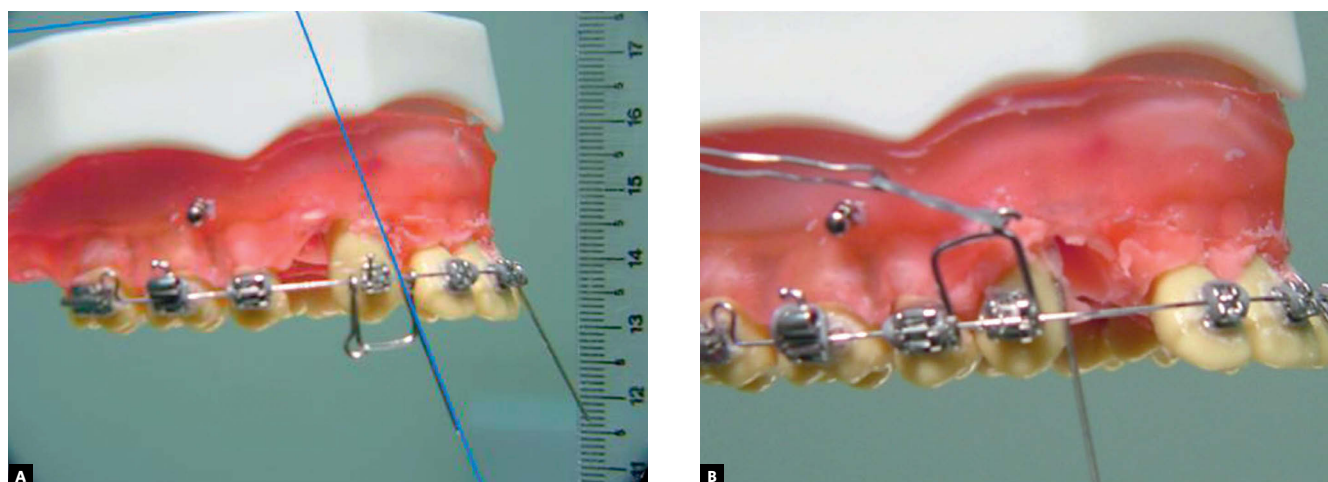


Figure 4 - A) Canine position before retraction with sliding jig; **B)** retracted canine.

Activation of the elastic chain was performed with the aid of a dynamometer, whose purpose was to activate and measure the force necessary for retraction.

The canines were retracted to an extension of 8 mm, and in each set, 15 repetitions were performed, thus enabling the groups to be statistically evaluated.

After data collection, statistical analysis was performed using the program SPSS 13.0 (SPSS Inc., Chicago, Illinois, USA). The amount of incisor extrusion, post-retraction canine tipping and force for retraction obtained in millimeters, angle and gram-force were submitted to the analysis of variance (ANOVA) to determine whether there were any statistical differences among the groups, and after this Tukey's test was performed.

RESULTS

The results demonstrated that the mini-implant/sliding jig system (Groups M 0.018-in and M 0.019 x 0.026-in) favored less extrusion of the incisors (Table 1) and greater distal tipping (Table 2) of the canines in the retraction stage ($p < 0.005$). The retraction system with elastic chain directly attached to orthodontic brackets (Groups C 0.018-in and 0.019 x 0.026-in) favored greater canine tipping

and incisor extrusion than the other groups, followed by the system of elastic chain attached to the hook (Groups G 0.018-in and 0.019 x 0.026-in).

However, regarding inclination, there were no statistical differences among the systems in which the elastic chain was placed directly onto the bracket and in which it was placed on the hook welded to the bracket ($p > 0.005$) (Table 2).

When the values of force required for canine retraction was evaluated, the Groups C 0.018-in and G 0.018-in required lower forces. Higher forces were required in Group M 0.019 x 0.026-in.

DISCUSSION

Precise knowledge of the mechanical implications of orthodontic appliances is a decisive factor for success or failure of the treated cases. The stage of retraction of the teeth is characterized as one of the most critical stages, requiring precise mechanical knowledge, thereby avoiding undesirable movements and loss of control during treatment.

Based on this premise, the aim of the present study was to evaluate the mechanical behavior of different methods of canine retraction, thus making it possible to provide the orthodontist with information which can be applied in daily clinical practice.

For this purpose a new methodology was developed, in which a dental Typodont was used, with teeth mounted on a heat sensitive wax base. This method was based on a Typodont method, which enabled evaluation of the extrusion and angulation movements.

When the incisor extrusion occurred during retraction was compared, Group C 0.018-in presented greater extrusion than the others. This could be justified by the more occlusal position of the force vector, so that it remained more distant from the

Table 1 - Amount of extrusion among groups.

Groups	Mean (mm)	s.d.	Statistical analysis*
C 0.018-in	2.6	0.4	A
G 0.018-in	0.6	0.1	B
M 0.018-in	0.1	0.2	C
C 0.019 x 0.026-in	1.9	0.3	D
G 0.019 x 0.026-in	0.5	0.1	B
M 0.019 x 0.026-in	0.1	0.2	C

* Equal letters mean absence of statistical differences.

Table 2 - Values of angulation acquired by canines post retraction.

Groups	Mean (mm)	s.d.	Statistical analysis*
C 0.018-in	-12	-3	A
G 0.018-in	-10	-3	A
M 0.018-in	-2	-2	B
C 0.019 x 0.026-in	-6	-2	C
G 0.019 x 0.026-in	-5	-3	C
M 0.019 x 0.026-in	-1	-2	B

* Equal letters mean absence of statistical differences.

Table 3 - Force required for canine retraction in the different systems.

Groups	Force variation (N)
C 0.018-in	150-320
G 0.018-in	160-310
M 0.018-in	160-370
C 0.019 x 0.026-in	160-390
G 0.019 x 0.026-in	155-380
M 0.019 x 0.026-in	165-430

center of resistance; and the greater flexibility presented by the 0.018-in steel wire in comparison with 0.019 x 0.026-in wire.

This provided greater distal tipping of the canine, and consequently, greater extrusion of the incisors. This fact may compromise esthetics with greater exposure of the incisors and gummy smile.

Group C 0.019 x 0.026-in was ranked second as the system in which most extrusion occurred. The discrete reduction in extrusion in comparison with Group C 0.018-in was due to the greater stiffness of the 0.019 x 0.026-in arch, favoring the fact that the results of the two groups differed statistically ($p < 0.05$).

Groups that were retracted with the sliding jig attached to mini-implants (M 0.018-in and 0.019 x 0.026-in) had the lowest values of incisor extrusion.

This fact is related to the proximity of the force vector to the center of resistance of the tooth, which allows better control of the distal tipping of the canine. The caliper of the arch was not shown to be important, since no statistical differences occurred between these two groups ($p > 0.05$).

Intermediate extrusion values were obtained with regard to retraction with elastic chain attached to a hook welded to the bracket (Groups G 0.018-in and 0.019 x 0.026-in). These values were due to the greater approximation of the force vector to the center of resistance, not as close as occurred in Groups M (0.018-in and 0.019 x 0.026-in) and not as distant as in Groups C (0.018-in and 0.019 x 0.026-in).

With regard to the angulation that the canines underwent during retraction, Groups M 0.018-in and 0.019 x 0.026-in, were shown to have less inclination than the other groups without statistical difference among them. Groups C 0.018-in and G 0.018-in were inclined with greater amplitude than the others, however, without statistical differences among them ($p > 0.05$). The conjunction of smaller arches (0.018-in) with a greater distance from the center of resistance was responsible for these results.

It is clinically important, whenever possible, to approximate the force vector to the center of resistance of the tooth to the maximum extent. Among the resources for this purpose, the accessory could be bonded in a more cervical direction, using longer hooks welded to the distal winglet of the bracket and sliding jig.

Another evaluated factor was the required force for retraction. Groups C 0.018-in and G 0.018-in, required lower forces than the other groups. Greater forces were required for Group M 0.019 x 0.026-in, as a result of the friction generated with the use of this arch. The groups in which retraction was performed with arch 0.018-in required lower forces than those performed in a rectangular arch. The group with the sliding jig probably required greater force due to the fact that this system produces more bodily movement (translation) than distal tipping. The greatest difficulty for bodily movement is the great amount of force necessary to do that.

CONCLUSIONS

By conducting this study, it could be concluded that:

- » Thicker arches presented greater vertical control and less distal tipping of the canines during retraction.
- » The use of the sliding jig attached to a mini-implant approximated the force vector to the center of resistance of the tooth, providing better mechanical control.

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Assessment of divine proportion in the cranial structure of individuals with Angle Class II malocclusion on lateral cephalograms

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Introduction: The study of the Divine Proportion ($\phi = 1.618$) began with the Greeks, having as main researchers the mathematician Pythagoras and the sculptor Phidias. In Dentistry, Ricketts (1981-82) was an early to study this issue.

Objective: This study proposed to evaluate how some cephalometric measures are presented in relation to the Divine Proportion, with the total of 52 proportions, formed by 28 cephalometric landmarks.

Methods: Lateral cephalograms of 40 Class II adults patients aging from 17 to 45 years (13 male and 27 female) were evaluated. The linear distances between the landmarks were measured using Radiocef Studio software.

Results: After statistical analysis, the data shown an average of 65,48% in the Divine Proportion, 17,5% in the relation Ans-Op/V1S-DM16 and 97,5% in the relations Na-Me/Na-PoNa e Na-PoNa/Na-Gn.

Conclusion: Among all cephalometric measurements investigated, the lower facial third and the dental arches showed the smallest percentages of Divine Proportion.

Keywords: Divine Proportion. Class II malocclusion. Cephalometry.

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INTRODUCTION

At this moment human beings are increasingly concerned about esthetics, beauty and harmonious shapes, specially facial ones.^{4,23,24} Such concern exists since pre-historic times, from the Paleolithic period until now.^{2,4} Beauty is a vital force that acts on the development of our lives and the human mind has been relentlessly searching for beauty in the different populations and periods.^{4,23} The search for prettier shapes that may satisfy the individual represents the endless desire for perfection and balance, leading to the concept of design and esthetics. However, the evaluation of beauty may be relative and abstract, i.e. something that is inside the mind of each person.

The dental treatment should follow artistic and scientific regulations. The teeth must be esthetically pleasant and fully functional with other facial structures. Orthodontists should not solely move teeth and gingiva by the fast techniques or strictly apply conventional methods. There is no universal treatment for all patients, since this might not be in accordance with nature and arts. The final goal after achieve a normal occlusion should be an improvement in facial esthetics. If the proportions are distorted instead of being reestablished, the employed method may have been unsuccessful and shall affect the final outcome. The association of scientific knowledge, meticulous and systematic observation, application of beauty rules, daily training and effort to improve health of the patient and beauty allows the clinicians to promote the health and happiness of patients.^{18,24}

The study of Divine Proportion was initiated by the Greeks, being the main researchers the mathematician Pythagoras and the sculptor Phidias. These investigators noticed that some findings were related to certain standards and numbers, which might explain the beauty and harmony observed in nature.^{9,10,11} The Divine Proportion is one of the most effective resources of esthetic proportionality available. It has been widely employed throughout the art history. The ancient Egyptians already knew the golden ratio and applied it in the construction of the pyramids. The Greeks employed it in their temples, the great artists in their paintings and sculptures, and even the great

composers applied it in their works. The Divine Proportion may be used for morphological analysis and esthetic evaluation of the teeth and facial skeleton and soft tissues, since many proportions found and defined as beautiful from human point of view, or comfortable and pleasant from a physical standpoint, display this proportion. Therefore, it was indicated for analysis of the structural harmony and may be applied in the orthodontic treatment planning, as well as in the planning of maxillofacial and plastic surgeries.^{14,19} Thus, the search for an ideal esthetics might be scientifically conducted instead using subjective perceptions.¹⁸

The investigation of this issue calls the interest of different areas such as Orthodontics, Maxillofacial Surgery, Plastic Surgery and Esthetics. It has also been applied in cephalometric analyses by authors such as Ricketts,¹⁸ Zietsman et al,²⁵ Gil,⁸ Gil and Medici Filho⁷ and Medici Filho et al¹⁴ who demonstrated the existence of Divine Proportion between different measurements of the human skull. According to Baker and Woods², few studies have been published on the Divine Proportion observed in the measurements of human skull. This demonstrates the importance of the present study, which aimed at evaluating the Divine Proportion in lateral cephalograms of Class II adult subjects, who were not submitted to previous orthodontic treatment.

MATERIAL AND METHODS

The sample comprised lateral cephalograms of 40 untreated Class II adult individuals (13 males and 27 females), aging from 17 to 45 years, with an ANB angle larger than 6° and no craniofacial deformities, syndromes or cleft lip and palate.

The work was carried out as follows:

- » The radiographs were digitized and recorded in a CD by means of a Scanjet HP 4C scanner (HP, Washington, USA) with transparency adapter. The images were stored in a computer and analyzed on the Radiocef Studio software (Radiomemory, Belo Horizonte, Brazil). Two cephalometric analyses were created, namely the Lateral Divine Analysis 1 (LDA1) and Lateral Divine Analysis 2 (LDA2). They employed the same cephalometric points available on the software,

besides some other landmarks suggested by Gil and Medici Filho¹² and demonstrated in Figure 1 and Table 1. The linear measurements were measured on the Radiocef Studio software. The analyses LDA1 and LDA2 comprised 52 factors each, and each factor of the LDA1 was divided by the corresponding factor on the LDA2. For example, the factor #1 of the LDA1 was divided by factor #1 of the LDA2 and so on up to factor #52 for verification of the presence or absence of Divine proportion in each radiograph. It should be highlighted that the larger value is always divided by the smaller value in order to facilitate the statistical calculations, i.e. the factors presented in LDA1 would be in Divine Proportion with their corresponding factors in LDA2 if this division yielded values ranging from 1.431 to 1.853, as advocated by Gil⁸ in 2001.

- » As an attempt to eliminate possible marking errors, each radiograph was traced twice, with a 15-day interval between them. Error calculation was conducted by the Intraclass Correlation Coefficient (ICC), which represents the total estimate of variability induced by individual variations. This coefficient estimates the degree of agreement between two values achieved in distinct moments.¹² The examinations were individually analyzed by the author by means of the LDA1 and LDA2, applied for each patient (Tables 2 and 3).
- » Statistical analysis of the linear measurements achieved by means of the LDA1 and LDA2 calculated on the Radiocef Studio software were conducted in order to observe the presence or absence of Divine Proportion in the human skull.

STATISTICAL ANALYSIS

Statistical analysis of the data was based on the following concept of divine proportion: One pair of measurements (A, B) is in Divine Proportion if $A/B = 1.618$, where $A > B$. The range from 1.431 to 1.853 was employed to assess the pairs of measurements in Divine Proportion, as suggested by Gil.⁷

The Minitab 13 software (Minitab Inc, State College, USA) was employed for calculation of the

divisions of the factors of LDA1 by those of LDA2 for each radiograph. It should be highlighted that this division was also performed by division of the largest value by the smallest value. After calculation of these proportions, the Statistix for Windows 7.0 software (Analytical Software, Tallahassee, USA) was used to submit the data to Descriptive Statistical Analysis (mean, standard deviation and median) at a confidence interval of 95%. This software also allowed calculation of the frequency distribution in order to establish how many factors in each radiograph were within the range established and, therefore, in Divine Proportion (Tables 1 and 2) (Fig 2).

RESULTS

Results are shown in Figure 2 and Tables 1 and 2.

DISCUSSION

The study of Divine Proportion in Dentistry was initiated in the 70s and 80s and was mainly conducted by Torres²² and Ricketts.^{18,19} Investigation of this subject has provided important contributions to the improvement and enhancement of the diagnosis and treatment planning of the patients, providing dentists a further instrument to evaluate whether shape, harmony, esthetics and craniofacial proportion are present.^{7,8,14,18,19,22,23,24}

The sample of the present study comprised 40 lateral cephalograms of 40 untreated Class II adult subjects (13 males and 27 females) with more than 17 years of age. Ricketts⁵ employed a sample of 30 lateral cephalograms of adult Peruvian male patients with normal occlusion and no admixture of races for assessment of the presence of Divine Proportion. Gil⁸ and Gil and Medici Filho⁷ observed the Golden Proportion in the cranial structures on a population of 23 untreated adult subjects with normal occlusion, of both genders, by means of lateral, frontal and axial cephalograms.

Some studies on Divine Proportion have regarded this method as effective for evaluation of beauty, harmony and proportion in objects such as paintings, buildings and even music compositions, as well as in several fields of science. Hintz and Nelson⁹, Piehl¹⁷ and Oliveira Junior¹⁵ concluded that noticeably prettier individuals presented a correspondence of 73.33% with the eight esthetic rules,

Table 1 - Landmarks constituting the LDA1 and LDA2 analyses.

#	Abbreviation	Definition of anatomical location
1	S	Center of the image of the pituitary fossa. For analysis of Schwarz, is the midpoint of the top opening of the pituitary cavity image.
2	Po	Uppermost point of the external auditory canal.
3	Op	Most low and posterior point of the foramen magnum.
4	Co	Upper posterior point of the mandibular condyle.
5	Me	Lowest point on the contour of the mandibular symphysis.
6	Pog	Most anterior point of the chin contour in the sagittal plane.
7	Gn	Point where the angle bisector between the mandibular plane and the N-Pog line intersects the external cortical of the mandibular symphysis.
8	Go	Point where the angle bisector formed by the tangent to the posterior edge of the ramus and the tangent to the lower limit of the mandibular body intersects the mandibular contour.
9	AM	Anterior point of the zygomatic bone below the orbit, corresponding to the cheek.
10	Ans	Most anterior point of maxilla.
11	Pns	Most posterior point of maxilla.
12	Or	Lowest point on the contour of the orbit.
13	POOr	Point in the occlusal plane, in the Or height.
14	SO	Most anterior and superior point of the orbit.
15	MdOr	Point in the lower cortical of mandible, in the Or height.
16	MxOr	Point in the upper portion of maxilla, in the Or height.
17	Na	Most anterior point of frontonasal suture.
18	Ptm	Most posterior superior point of pterygomaxillary fossa.
19	AA	Insertion of the extension of the maxillary plane with posterior ramus.
20	MxNa	Upper part of maxilla, at Na height.
21	PONa	Point on occlusal plane, at Na height.
22	IMPt	Point on lower cortical of mandible, at Ptm height.
23	IMPM	Point on lower portion of mandible, at Pns height.
24	C1MS	Point in the center of upper first molar.
25	V1S	Point on the buccal of the maxillary incisor.
26	DM16	Distal point on the mandible, at the height of C1MS-V1S line.
27	AcrS	Point on anterior portion of skull, at sella plane height - anterior base of skull.
28	ASPt	Anterior superior point of the pterygomaxillary fossa.

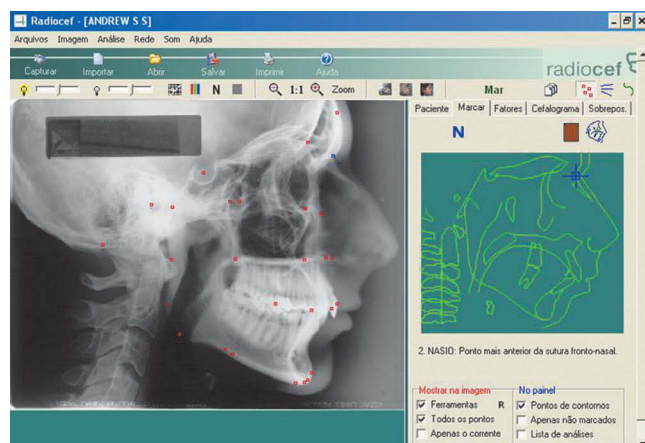
**Figure 1** - Landmarks constituting the LDA1 and LDA2 analyses.

Table 2 - Lateral Divine Analysis 1.

Computerized Cephalometrics - Lateral Divine Analysis 1				
Patient:		Age:	Gender:	
Orthodontist:		Date:		
Factors	Landmarks 1	Value found	Landmarks 2	
1	Na-Me	Na	0.00 Me	
2	Na-Me	Na	0.00 Me	
3	Na-Me	Na	0.00 Me	
4	Ans-Me	Ans	0.00 Me	
5	Ans-Me	Ans	0.00 Me	
6	Na-Ans	Na	0.00 Ans	
7	Na-Ans	Na	0.00 Ans	
8	Na-Ans	Na	0.00 Ans	
9	Na-Ans	Na	0.00 Ans	
10	Na-Ans	Na	0.00 Ans	
11	Na-Ans	Na	0.00 Ans	
12	Na-Ans	Na	0.00 Ans	
13	Na-Poor	Na	0.00 Poor	
14	Na-Poor	Na	0.00 Poor	
15	Na-Poor	Na	0.00 Poor	
16	Na-Poor	Na	0.00 Poor	
17	Na-Poor	Na	0.00 Poor	
18	Pt-IMPt	Pt	0.00 IMPt	
19	Pt-IMPt	Pt	0.00 IMPt	
20	Pt-IMPt	Pt	0.00 IMPt	
21	Pns-ImPm	Pns	0.00 ImPm	
22	Pns-ImPm	Pns	0.00 ImPm	
23	SO-Or	SO	0.00 Or	
24	SO-Or	SO	0.00 Or	
25	SO-Or	SO	0.00 Or	
26	A-Pog	A	0.00 Pog	
27	A-Pog.	A	0.00 Pog.	
28	A-Pog.	A	0.00 Pog.	
29	A-Pog.	A	0.00 Pog.	
30	A-Pog.	A	0.00 Pog.	
31	Ans-Pns	Ans	0.00 Pns	
32	Ans-Pns	Ans	0.00 Pns	
33	Ans-Pns	Ans	0.00 Pns	
34	Ans-Pns	Ans	0.00 Pns	
35	Ans-Pns	Ans	0.00 Pns	
36	Ans-Pns	Ans	0.00 Pns	
37	Pog-Op	Pog	0.00 Op	
38	Pog-Op	Pog	0.00 Op	
39	Pog-Op	Pog	0.00 Op	
40	Pog-Op	Pog	0.00 Op	
41	Na-Op	Na	0.00 Op	
42	Na-Op	Na	0.00 Op	
43	Na-Op	Na	0.00 Op	
44	Na-Op	Na	0.00 Op	
45	Na-Op	Na	0.00 Op	
46	Ans-Op	Ans	0.00 Op	
47	Ans-Op	Ans	0.00 Op	
48	Ans-Op	Ans	0.00 Op	
49	V1S-C1MS	V1S	0.00 C1MS	
50	V1S-C1MS	V1S	0.00 C1MS	
51	Mdor-Poor	Mdor	0.00 Poor	
52	Mdor-Poor	Mdor	0.00 Poor	

Table 3 - Lateral Divine Analysis 2.

Computerized Cephalometrics - Lateral Divine Analysis 2				
Patient:		Age:	Sex:	
Orthodontist:		Date:		
Factors	Landmarks 1	Value found	Landmarks 2	
1	Ans-Me	Ans	0.00 Me	
2	Na-PoNa	Na	0.00 PoNa	
3	Pt-IMPt	Pt	0.00 IMPt	
4	Na-Gn	Na	0.00 Gn	
5	Co-Gn	Co	0.00 Gn	
6	Ans-AA	Ans	0.00 AA	
7	Go-Pog	Go	0.00 Pog	
8	Na-PoNa	Na	0.00 PoNa	
9	Or-Me	Or	0.00 Me	
10	V1S-AA	V1S	0.00 AA	
11	Pns-Op	Pns	0.00 Op	
12	S-Acrs	S	0.00 Acrs	
13	Co-Gn	Co	0.00 Gn	
14	Na-Gn	Na	0.00 Gn	
15	Pns-IMPm	Pns	0.00 IMPm	
16	Na-MxN	Na	0.00 MxN	
17	Or-Poor	Or	0.00 Poor	
18	Co-Gn	Co	0.00 Gn	
19	Na-Gn	Na	0.00 Gn	
20	Pns-IMPm	Pns	0.00 IMPm	
21	Go-Pog	Go	0.00 Pog	
22	Co-Am	Co	0.00 Am	
23	Mxor-So	Mxor	0.00 So	
24	Mxor-Mdor	Mxor	0.00 Mdor	
25	Ans-Pog	Ans	0.00 Pog	
26	Or-Me	Or	0.00 Me	
27	Po-Na	Po	0.00 Na	
28	V1S-C1MS	V1S	0.00 C1MS	
29	V1S-AA	V1S	0.00 AA	
30	V1S-AA	V1S	0.00 AA	
31	V1S-C1MS	V1S	0.00 C1MS	
32	Op-Pns	Op	0.00 Pns	
33	Or-Me	Or	0.00 Me	
34	SO-Poor	SO	0.00 Poor	
35	Ans-AA	Ans	0.00 AA	
36	Op-Pns	Op	0.00 Pns	
37	Op-ASPt	Op	0.00 ASPt	
38	Or-Me	Or	0.00 Me	
39	Go-Pog	Go	0.00 Pog	
40	V1S-AA	V1S	0.00 AA	
41	Op-Pns	Op	0.00 Pns	
42	SO-Poor	SO	0.00 Poor	
43	Or-Me	Or	0.00 Me	
44	Go-Pog	Go	0.00 Pog	
45	V1S-AA	V1S	0.00 AA	
46	Op-Pns	Op	0.00 Pns	
47	Go-Pog	Go	0.00 Pog	
48	V1S-AA	V1S	0.00 AA	
49	Ans-Pns	Ans	0.00 Pns	
50	Ans-Pog	Ans	0.00 Pog	
51	Mxor-Mdor	Mxor	0.00 Mdor	
52	Mxor-Poor	Mxor	0.00 Poor	

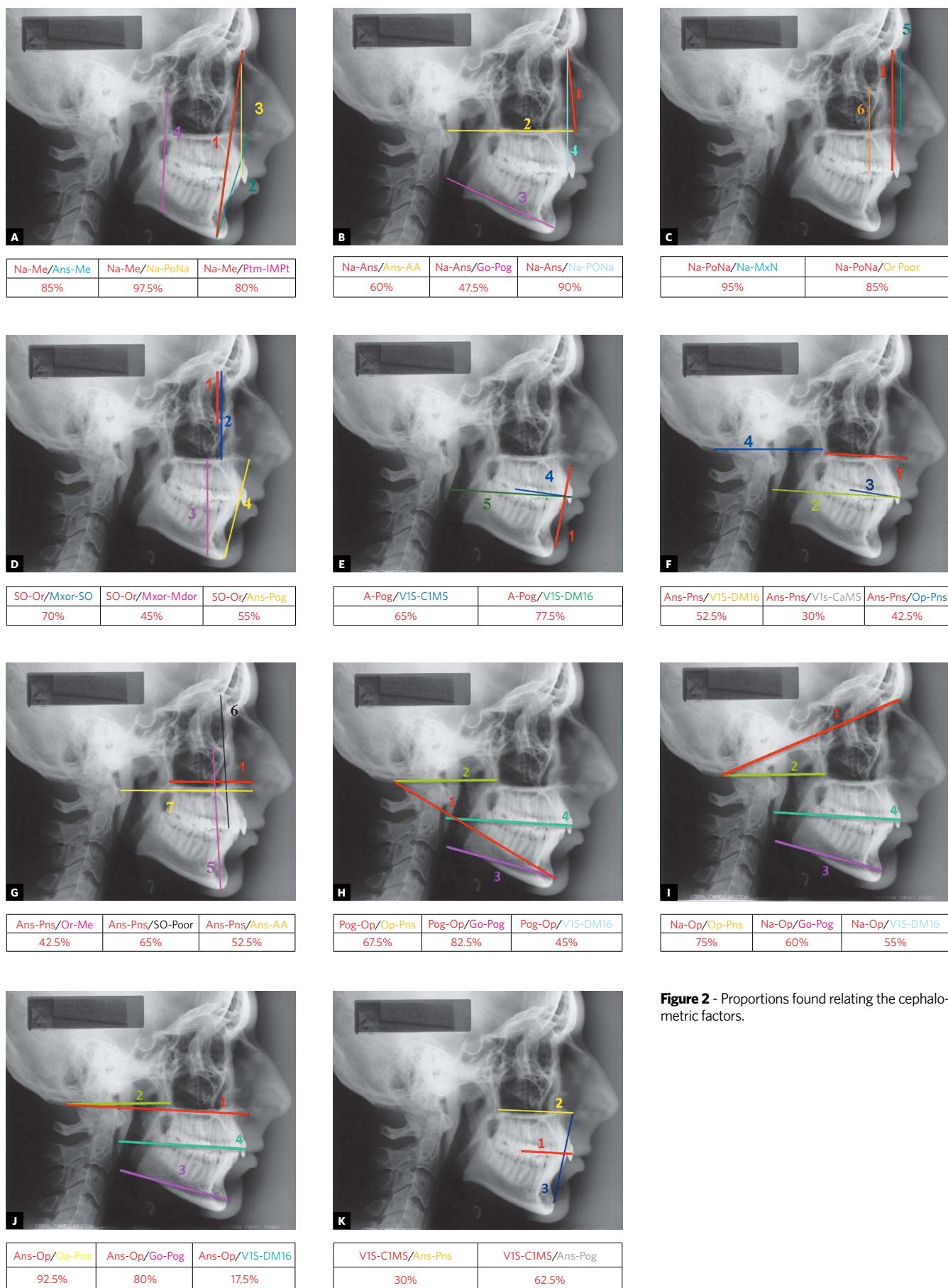


Figure 2 - Proportions found relating the cephalometric factors.

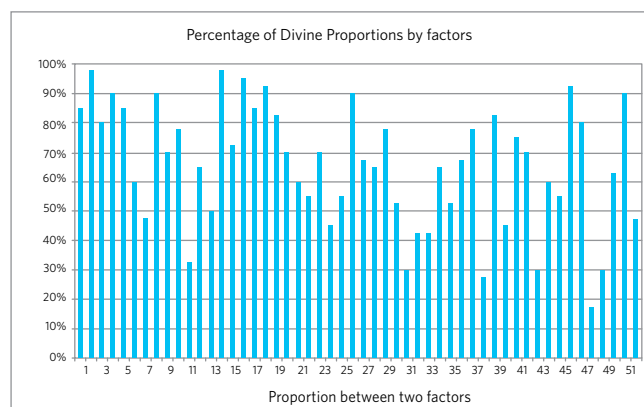


Figure 3 - Graphic of percentages of divine proportion between factors.

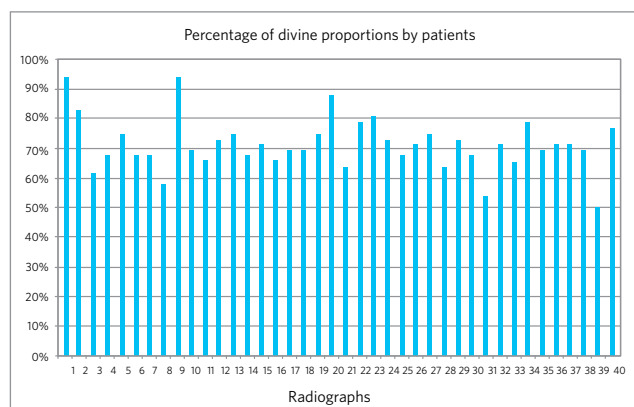


Figure 4 - Graphic of percentages of divine proportion between patients.

including some of Divine Proportion, whereas the non-pretty subjects displayed a correspondence of just 38.33%. The present study did not evaluate the patient's attractiveness, since our sample suggests the presence of a facial esthetic imbalance secondary to the Angle Class II malocclusion present.

Ricketts,¹⁸ Zietsman et al,²⁵ Garbin,^{5,6} Piccin,¹⁶ Snow,²¹ Araújo et al¹ and Oliveira Junior¹⁵ conducted specific investigations on the oromaxillofacial structures and also found Divine Proportion. For example, Ricketts¹⁸ observed this proportion in horizontal and vertical measurements. Gil,⁸ Gil and Medici Filho⁷ and Medici Filho¹⁴ found the presence of several measurements in Golden Proportion, which were related to each other in several manners and provided the human skull with an effective balance. These findings strongly suggested that the skull, as well as other structures in nature, follows the laws of conservation of energy and thus is a very effective structure in both shape and composition. In the present study, many structures were found to be in Divine Proportion, as demonstrated on the tables and figures.

Radiographic cephalometrics consists on the measurement of physical, linear and angular dimensions in skull radiographs. It is a very good auxiliary and supplementary instrument for diagnosis and may even be regarded as essential for observation of growth and evaluation of orthodontic treatments. This technique has been and still is the most widely employed for assessment of the facial growth, facial profile and also of the relationship

between maxilla and mandible in human beings. Some authors have employed it to investigate the presence of Divine Proportion in the oromaxillofacial structures and achieved satisfactory outcomes (Ricketts,¹⁸ Zietsman et al,²⁵ Garbin,^{5,6} Araújo et al,¹ Baker and Woods,⁴ Gil and Medici Filho,⁷ Medici Filho et al¹⁴). The present study comprised evaluation of measurements of the human skull structure by means of landmarks and factors measured on lateral cephalograms, by means of a computerized cephalometric software called Radiocef Studio. According to Martins¹³ and Brangeli,³ the advent of informatics and its application in clinical cephalometrics has provided high-technology resources for the achievement of elements of diagnosis and also for manipulation of such elements, for the accomplishment of projections, analyses and treatment simulations, enhancing and facilitating selection of the best therapeutic approach. On the other hand, there may be errors in the cephalometric analyses with employment of the computer, leading to doubtful measurements with employment of this method. Error control is fundamental for the outcomes of cephalometric investigations to be valid.¹⁰

Now we are going to discuss the results of Divine Proportions observed in the present study, which shall be divided by groups of factors of cephalometric measurements in order to make interpretation of such outcomes easier.

Correlation between vertical distances such as Na-Me / ANS-Me, Na-Me / Na-PoNa, Na-Me / Ptm-IMPt (Fig 2A) revealed Divine Proportion in more

than 80% of the sample, suggesting that even in the presence of Class II malocclusions the muscle forces that define the vertical dimension were present and could provide balance, harmony and even a proper facial proportion. It should be noticed that Na-Me represents the anterior facial height of the patient in frontal view and was in Divine Proportion with the intermaxillary distance (ANS-Me) when in occlusion. In 1982, Ricketts¹⁸ found Divine Proportion when related similar measurements to Na-Me and ANS-Me in soft tissue, using photographs of beautiful women (models) of different races.

The present results are also in agreement with Gil⁸ and Gil and Medici Filho,⁷ who also observed a percentage of Golden Proportion above 80% in an evaluation of lateral cephalograms of patients with normal occlusion.

Relationship between measurements comprising just one point at the maxilla and another at the skull, Na-ANS / Na-PONa, (Fig 2B), revealed the presence of Divine Proportion in 90% of the sample. However, the observation of the correlation Na-ANS / ANS-AA, on which one cephalometric point is located at the mandible (AA), the percentage of Divine Proportion was decreased to 60% of the sample. Moreover, the correlation Na-ANS / Go-Pog, which related one factor with one point at the maxilla and another at the skull to another factor measured just in the mandible, revealed the presence of Divine Proportion in just 47.5% of the cases. These values are different from the findings of Gil,⁸ and Gil and Medici Filho,⁷ which observed Divine Proportion in such relationship in more than 80% of the sample. This difference might be assigned to a retruded mandible in relation to the maxilla as observed in Class II patients.

Figure 2C demonstrates the presence of Divine Proportion in 95% of the patients for Na-PoNa / Na-MxN and 85% of the patients for Na-PoNa / Or-Poor; these factors are located just at the maxilla and facial bones and therefore are not influenced by the disproportion existing between maxilla and mandible of Class II patients. These observations were in agreement with Gil,⁸ Gil and Medici Filho.⁷

The measurements SO-Or / Mxor-SO (Fig 2D), which are measurements of the maxilla and upper facial third, displayed a higher percentage of Divine

Proportion (70%) than the measurements SO-Or / Mxor-Mdor and SO-Or / ANS-Pog, 45% and 55% respectively, which comprise maxillary and mandibular measurements and therefore are more susceptible to the alterations observed in subjects with malocclusion. For that reason, these outcomes disagree with the findings of Gil,⁸ and Gil and Medici Filho.⁷

Divine Proportion was observed in 65% of cases for the A-Pog / V1S-C1MS and in 77.5% for A-Pog / V1S-DM16 (Fig 2E). These factors are prone to variations that are directly related to occlusal disturbances, since they are horizontal factors on the maxilla and thus may vary with the mandibular retraction in relation to the maxilla. Another possible explanation for this reduced ratio of Divine Proportion might be the involvement of factors based on points on the teeth, which are similarly influenced by malocclusions. Thus, these percentages of Divine Proportions were smaller than those observed by Gil⁸ and Gil and Medici Filho,⁷ who found the presence of Divine Proportion in more than 80% of the subjects in skeletal and dental measurements and also on dental and skeletal measurements on the maxillary incisors.

The comments on Figure 2E are confirmed in Figure 2F, which demonstrates presence of Divine Proportion for the horizontal measurements in 42.5% for the ANS-PNS / Op-Pns and 52.5% for the ANS-PNS / V1S-DM16, i.e., factors influenced by the anterior posterior relationship between maxilla and mandible, and in 30% for ANS-PNS / V1S-C1MS, which also involved the teeth.

Araújo et al¹ observed that the patients presented different responses to treatment and found statistical differences in the outcomes between the pre- and post-operative data in the proportions A-1 / 1-Pm and Co-Xi / Xi-Pm. Yet this did not occur for the proportion Pfr-A / A-Pm, which presented a significant difference, revealing no alterations with surgery from an esthetic point of view. The authors explained that the vertical measurements, compared to the Co-Xi / Xi-PM measurement, displayed a smaller alteration with the mandibular advancement, which provides a larger change in anterior posterior than in vertical direction.

As regards the ratio ANS-PNS / V1S-C1MS, there may also be a larger growth of the maxillary

base ANS-PNS in relation to the arch size V1S-C1MS, which leads to such disharmony. Similarly, Figure 2G reveals presence of Divine Proportion in 42.5% for ANS-PNS / Or-Me, 65% for ANS-PNS / SO-Poor and 52.5% for ANS-Pns / ANS-AA. Therefore, the ratios between cephalometric factors displayed a smaller percentage of Divine Proportion than reported by Gil⁸ and Gil and Medici Filho.⁷

According to Gil,⁸ when one factor in the groups of measurements Pog-Op, Na-Op and ANS-Op is in proportion with one of these measurements, it shall also be in proportion with the other two measurements. The three measurements were regarded as equal in his study. However, in the present study the relationship between the factors Pog-Op, Na-Op and ANS-Op with each of the factors Op-PNS, Go-Pog and V1S-DM16 (Fig 2H, I and J) presented different results, as shown in Table 4.

Figure 2L represents positioning of the maxillary incisor and maxillary first molar, which refer to the anterior posterior positioning of the tooth, an important aspect for Class II patients. Correlation between factors of horizontal dimensions, (V1S-C1MS/ANS-PNS) revealed Divine Proportion in 30% of the patients, yet the correlation between one horizontal and one vertical factor (V1S-C1MS / ANS-Pog) displayed a percentage of Divine Proportion of 62.5%. These relationships displayed a larger percentage of Divine Proportion in the study of Gil⁸ and Gil and Medici Filho.⁷

In general, calculation of the mean of percentages of the 52 correlations between the cephalometric factors investigated revealed a rate of 65.48% of Divine Proportion, different from the outcomes of Gil⁸ and Gil and Medici Filho,⁷ who found a percentage above 80%. Moreover, Divine Proportion was observed in 17.5% for the ANS-Op/V1S-DM16 relationship and 97.5% for the Na-Me/Na-PoNa and Na-PoNa/Na-Gn correlations, which were the

Table 4 - Percentage of ratios observed upon relationship between Pog-Op, Na-Op and ANS-Op factors with each of the factors Op-PNS, Go-Pog and V1S-DM16.

Pog-Op / Op-Pns	Pog-Op / Go-Pog	Pog-Op /V1S-DM16
67.5%	82.5%	45%
Na-Op / Op-Pns	Na-Op /Go-Pog	Na-Op /V1S-DM16
75%	60%	55%
Ans-Op /Op-Pns	Ans-Op /Go-Pog	Ans-Op /V1S-DM16
92.5%	80%	17.5%

lowest and highest percentages of Divine Proportion observed in the present sample, respectively.

During the development of this study and in agreement with the literature review, it could be noticed that even though the discovery of the Divine Proportion is very old, its study and application in health specialties and mainly in Dentistry are based on few studies. Investigations on this subject have been conducted since the ancient Greece, yet just in 1982 Ricketts¹⁸ demonstrated the presence of Divine Proportions in lateral cephalograms. As described, the Divine Proportion may play a very important role in the evaluation of diagnosis and also as an auxiliary therapeutical tool in Dentistry.

CONCLUSIONS

Based on these methods and on the analysis of the results achieved, the following could be concluded on the cranial structure of untreated Class II adult subjects:

- » There was a mean percentage of 65.48% of the cephalometric measurements in Divine Proportion.
- » Among all cephalometric measurements investigated, the lower third of the head, as well as the dental arches of the individuals in this sample, were the areas on which the proportions displayed the smallest percentages of Divine Proportion.

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Orthodontics as a therapeutic option for temporomandibular disorders: A systematic review

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Objective: Orthodontics as an option for treatment and prevention of Temporomandibular Disorders (TMD) is a topic that has generated discussion over time. While an occlusion current defends Orthodontics as an alternative to treatment, another current defends more conservative and reversible treatments. The objective of this study, through a systematic literature review, was to analyze the relationship between Orthodontics and TMD, checking the effects of orthodontic therapy in treatment and prevention of TMD.

Methods: Survey in research bases: MEDLINE, Cochrane, EMBASE, Pubmed, Lilacs and BBO, between the years of 1966 and May 2009, with focus in randomized clinical trials, non-randomized prospective longitudinal studies, systematic reviews and meta-analysis was performed.

Results: After application of the inclusion criteria 11 articles were selected, 9 which were non-randomized prospective longitudinal studies, 1 randomized clinical trial and 1 systematic review.

Conclusions: According to the literature, there is a lack of specific studies that evaluated Orthodontics as an option for treatment and prevention of TMD. Thus the data conclude that there is no significant scientific evidences that orthodontic treatment treats or prevents TMD.

Keywords: Temporomandibular joint dysfunction syndrome. Temporomandibular joint disorders. Craniomandibular disorders. Temporomandibular joint. Orthodontics. Dental occlusion.

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INTRODUCTION

The relationship between orthodontic treatment and Temporomandibular Disorders (TMD) consists of a subject that raises doubts about the real role of Orthodontics in treatment and prevention of TMD. In the recent past, dental occlusion was considered the main causal factor of TMD, and orthodontic treatment consisted a primary therapeutic measure for a physiologic restoration of the stomatognathic system. Over time, the etiology of TMD has been considered as multifactorial, being associated with other contributing factors such as the presence of parafunctional habits, anatomical and neuromuscular factors, systemic changes, psychological conditions and postural alterations.^{3,21}

With the accomplishment of studies with adequate designs and precise and rigorous methodological criteria, the interface Orthodontics–TMD can be analysed critically. Thus, the general aim of this study, through a systematic literature review, was to analyse in a context of a scientific evidence based Dentistry, the inter-relation of TMD and Orthodontics, and specifically assess the effects of orthodontic therapy in the treatment and prevention of TMD.

MATERIAL AND METHODS

We performed a computerized search in MEDLINE, Cochrane, EMBASE, PubMed, Lilacs and BBO in the period from 1966 to May 2009. The research descriptors used were “orthodontics”, “orthodontic treatment”, “temporomandibular disorder,” “temporomandibular joint”, “cranio-mandibular disorder”, “TMD,” “TMJ,” “malocclusion” and “dental occlusion”, which were crossed in search engines. The initial list of studies was subjected to review by two reviewers, who applied inclusion criteria to determine the final sample of articles, which were assessed by their title and abstract. If there was any disagreement between the results of the reviewers, a third appraiser would participate by reading the full version of the article.

Inclusion criteria for selecting articles were:

- » Studies which evaluated the effectiveness of orthodontic treatment in the treatment and prevention of Temporomandibular Disorders (TMD), and in which Orthodontics was compared to no treatment, placebo, oral appliances,

pharmacological treatment and physical and relaxation therapies.

- » Studies in which orthodontic treatment is already completed in the samples.
- » Randomized clinical trials (RCTs), non-randomized prospective longitudinal studies, systematic reviews and meta-analysis.
- » Studies written in English and published between 1966 and May 2009.

Thus, we excluded case reports, case series, cross-sectional studies, simple reviews and authors opinions, as well as studies in which the orthodontic treatment has not been completed.

RESULTS

After applying the inclusion criteria 11 studies were obtained and the Kappa index of agreement between reviewers was 1.00. Of these, nine were non-randomized prospective longitudinal studies, one was a randomized clinical trial and one was a systematic review (Fig 1).

The sample of selected articles are presented in Tables 1 and 2.

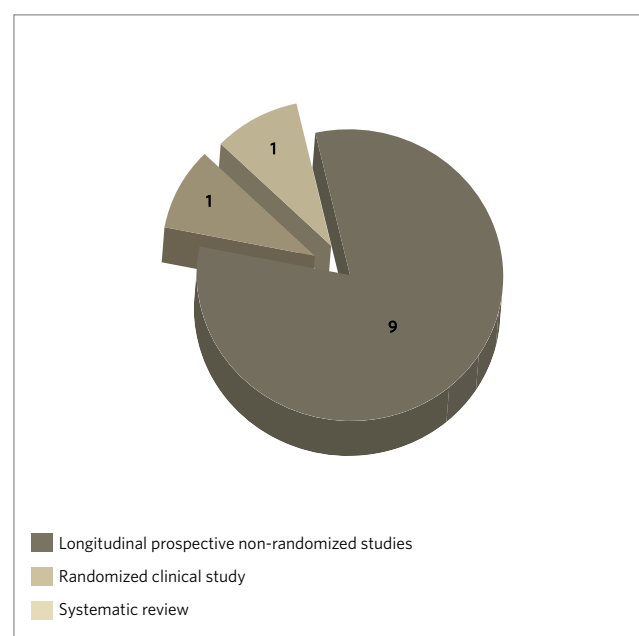


Figure 1 - Design of included studies.

Table 1 - Included studies design.

Authors	Year of publication	Study design	Sample size (N)	Control	Orthodontic appliance type
Egermark and Thilander ⁶	1992	P, L	402 mixed	Yes	FA, F
Rendell et al ²²	1992	L	- 451 without TMD - 11 with TMD	No	F
Egermark and Ronnerman ⁵	1995	L	50 tt - 135 no tt	Yes	FA, F
Keeling et al ¹⁵	1995	RCT	60 tt Bionator - 71 tt AEB - 60 no tt	Yes	FA
Olsson and Lindqvist ²⁰	1995	P, L	210 tt	No	F
Mcnamara and Turp ¹⁷	1997	SR	21 studies	-	FA, F
Henrikson et al ¹³	1999	P, L	65 tt	No	F
Henrikson and Nilner ¹¹	2000	P, L	65 tt - 58 no tt (Class II) - 60 no tt (normal)	Yes	F
Henrikson et al ¹⁴	2000	P, L	65 tt - 58 No tt (Class II) - 60 no tt (normal)	Yes	F
Henrikson and Nilner ¹²	2003	P, L	65 tt - 58 no tt (Class II) - 60 no tt	Yes	F
Mohlin et al ¹⁸	2004	P, CC	72 without TMD - 62 with TMD	Yes	FA, F

P: prospective, L: longitudinal, RCT: randomized clinical trial; SR: systematic review; CC: case-control; tt: treatment, F: fixed appliances; FA: functional appliances; H: headgear; NS: Not specified.

Table 2 - Included studies Results

Authors	Time of assessment	Diagnostic criteria for TMD	Main objective of the study	Relationship between Orthodontics and TMD
Egermark and Thilander ⁶	10 years	Questionnaire, Helkimo index	TMD prevalence in patients orthodontically treated and untreated	Treated patients: Lower prevalence of TMD
Rendell et al ²²	During tt	Helkimo index	Orthodontics as a risk factor for TMD?	Improvement in patients with TMD
Egermark and Ronnerman ⁵	Before, during, after tt	Questionnaire, Helkimo index	TMD prevalence in patients orthodontically treated and untreated	Improvement of the signs and symptoms of TMD and headaches
Keeling et al ¹⁵	Follow-up of 2 years	TMJ sound and pain, muscle pain	Orthodontics as a risk factor for TMD?	Bionator: improvements in capsular pain in some children
Olsson and Lindqvist ²⁰	After tt	Questionnaire, Helkimo index	Influence of orthodontic treatment on mandibular function	Improvement in patients with TMD
Mcnamara and Turp ¹⁷	-	-	The role of Orthodontics in the development, prevention and treatment of TMD	Lack of reliable scientific evidence
Henrikson et al ¹³	Before, during, after tt and 1 year after 1st evaluation	Signs and symptoms	Prevalence of signs and symptoms of TMD before, during and after tt	Decrease in symptoms and muscle sensitivity to palpation
Henrikson and Nilner ¹¹	2 years after 1st evaluation	Symptoms (headaches, pain, TMJ sound)	Prevalence of TMD symptoms in patients orthodontically treated and not treated	Improvement of symptoms of TMD
Henrikson et al ¹⁴	2 years after 1st evaluation	Signs (mandibular movements, pain, TMJ sound)	Prevalence of TMD signs in patients orthodontically treated and not treated	Improvement of signs of muscle TMD
Henrikson and Nilner ¹²	Beginning, after 1 and 2 years of tt and 1 year after the end of tt	Signs and symptoms	Prevalence of TMD signs and symptoms in patients orthodontically treated and not treated	Improvement of signs and symptoms of muscle TMD
Mohlin et al ¹⁸	Performed at 19 and 30 years old	Questionnaire, clinical assessment, psychological status	The role of Orthodontics in the development, prevention and treatment of TMD	Without evidence that Orthodontics is a preventive therapy for TMD

tt: treatment; MM: mandibular movements; NS: not specified.

DISCUSSION

The knowledge about the methodological criteria that qualify the scientific research becomes increasingly necessary in the current context of a scientific evidence based Dentistry. Thus, appropriate study designs, associated with methodological criteria such as randomization, calibration, sample size calculation, blinding, control factors, pairings for sex and age, among others, qualify the evidence generated and provide more precise scientific information.²³ This knowledge is important, since most publications in national journals are studies of low potential for direct clinical application.¹⁹

Likewise, the design of clinical trials allows a qualification of scientific evidence generated. Cross-sectional studies allow the study of associations that identify risk indicators and generate hypotheses. Subsequently, these hypotheses need to be tested in longitudinal studies to identify true risk factors²⁴. Due to this fact, the methodology of this systematic review included only longitudinal studies, systematic reviews and meta-analysis.

The results of this systematic review demonstrate a very limited number of specific studies about the role of orthodontic treatment in patients with signs and symptoms of TMD. Much of the selected studies aimed to evaluate first Orthodontics as a causal factor for the development of TMD, and secondarily to verify its role in the prevention and treatment of TMD. With this lack of clinical studies and significant evidences, such as RCTs, systematic reviews and meta-analysis, it becomes difficult to obtain accurate conclusions and extrapolate the results to the general population.

Some studies were suggestive of improvement in cases of TMD due to orthodontic treatment.^{5,6,11-15,20,22} However, the results of these publications are subjective, since the main objective of most of these studies was to assess the prevalence of TMD in patients treated or not treated orthodontically^{5,6,11-14} or evaluate Orthodontics as possible risk factor for development of TMD.^{15,22} Thus, these publications had limitations, due to its main objective and the sample size of patients with pretreatment TMD. Still, other studies have proposed to specifically assess Orthodontics as a therapeutic option for muscular TMD, but as there was no revaluation at the end of treatment, they were not included in this systematic review.^{1,2}

The studies that suggest a lower prevalence of TMD in orthodontically treated patients when compared to untreated individuals, showed greater benefit in muscle TMD,^{12,13,14} while only one study related improvements in joint pain¹⁵. In relation to the preventive role of orthodontic treatment in the development of TMD, some studies correlate this association in a positive⁶ and others in a negative way.^{17,18} But the systematic analysis of the literature demonstrates a lack of specific scientific evidence about the performance of orthodontic treatment in the treatment and prevention of TMD.^{17,18}

Still, there is need for further controlled randomized clinical trials with rigorous methodological criteria and with the specific objective of assessing orthodontic therapy as a treatment option in patients with TMD. However, the difficulty of conducting RCTs involving Orthodontics and TMD is known, due to ethical and practical reasons¹⁶. Moreover, it is important to adopt universal and standardized diagnostic criteria for TMD, which would contribute to reducing the heterogeneity of the results obtained in various studies, since there are different diagnostic criteria: Craniomandibular Index,^{7,8} Helkimo Index,^{9,10} variations and adaptations of these and more recently the RDC/TMD.⁴

Therapies that change the occlusal pattern in a definitive manner, such as orthodontic treatment and occlusal adjustment, are not indicated and supported by significant scientific evidences as initial protocols of treatment for TMD. In patients with Temporomandibular Disorders conservative and reversible treatments as the initial protocol should be adopted, and then after their control and management, check the necessity of providing orthodontic procedures and prosthetic rehabilitation.

CONCLUSIONS

- » There is no specific evidence based on randomized clinical trials, systematic reviews and meta-analysis, that orthodontic therapy is a therapeutic option for treatment, control and prevention of TMD.
- » Some studies have demonstrated improvement in signs and symptoms of TMD in patients undergoing orthodontic treatment when compared to individuals who did not

receive Orthodontics. However, these results are only suggestive, since it had limitations in relation to sample size and the main objective of the study.

- » There is a need to assess Orthodontics as treatment and as prevention option for TMD

based on studies with appropriate designs and rigorous methodological criteria. Thus, the relationship between Orthodontics and TMD should be based on controlled randomized clinical trials, systematic reviews and meta-analysis for more precise conclusions.

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In vitro evaluation of flexural strength of different brands of expansion screws

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Objective: The objective of this study was to compare the flexural strength of the stems of three maxillary expanders screws of Morelli, Forestadent and Dentaaurum brands.

Methods: The sample consisted of nine expander screws (totalizing of 36 stems), three from each brand, all stainless steel and 12 mm of expansion capacity. The stems of the expander screws were cut with cutting pliers close to the weld region with screw body, then fixed in a universal testing machine Instron 4411 for tests of bending resistance of three points. The ultimate strength in kgF exerted by the machine to bend the stem of the 5 mm screw was recorded and the flexural strength was calculated using a mathematical formula. During the flexural strength test it was verified the modulus of elasticity of the stems by means of Bluehill 2 software. The flexural strength data were subjected to ANOVA with one criterion and Tukey's test, with significance level of 5%.

Results: Forestadent screw brand showed the greatest bending strength, significantly higher than Dentaaurum. Morelli showed the lowest resistance.

Conclusion: The flexural strength of the screws varied according to the brand. Forestadent screw showed the greatest resistance and Morelli the lowest. All the three screws were found adequate for use in procedures for rapid maxillary expansion.

Keywords: Palatal expansion technique. Corrective orthodontics. Malocclusion.

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INTRODUCTION

Rapid maxillary expansion (RME) has been shown to be an efficient method for correcting skeletal posterior crossbite^{6,16}. The success of RME performed in young patients may also be extended to adult patients by means of surgically assisted maxillary expansion.¹¹ To increase the efficiency of the forces generated by the expansion screw, osteotomies are performed attenuating the stress generated by osseous attachments releasing the median palatine suture.^{3,4} This procedure optimizes the orthopedic effect preventing the undesirable dental effects represented by the inclination of the teeth.^{1,10}

The force released by the expanders produces areas of compression in the periodontal ligament of the supporting teeth, leading to bone resorption and subsequent dental movement. Expander appliances such as Hyrax type, which concentrate the force in the dentoalveolar areas, may be more iatrogenic from the periodontal point of view and may cause more root resorption than the expanders of the Haas type, which distribute the force among the anchorage teeth and the surface of the palate.¹⁵

There are important differences between facial orthopedic procedures that use rapid expansion or just simple orthodontic procedures. Orthodontic mechanics are used aiming constant forces application for a long period of time, seeking more physiological, skeletal and periodontal responses. Whereas the rapid maxillary expansion produces heavy forces aiming minimum dental movement and maximum orthopedic response. Therefore, it is fundamental that maxillary expansion appliances have sufficient resistance to bear the required forces for facial orthopedic procedures.

The application of orthodontic forces during rapid maxillary expansion, the effects on sutures, teeth and periodontium, as well as types of appliance has been extensively evaluated.^{2,7,17,5} However, there is a notable lack of studies related to the resistance of screws used in rapid maxillary expansion. The resistance of expansion appliances has a direct influence on the amount of force transmitted to the teeth and, consequently, to the median palatine suture region. Therefore, the aim of this study was to evaluate the three point flexural bending resistance of the bars of expansion screws used in rapid maxillary expansion procedures.

MATERIAL AND METHODS

The sample consisted of 3 expansion screws from 3 different manufactures (Morelli, Dentaureum and Forestadent). Each expansion screw is composed of 4 bars, totalizing 12 bars per group (n=12). The characteristics of the screws used are described in Table 1.

Three point flexural bending test

For the three point flexural bending test, the bars of the maxillary expansion appliances were cut with pliers suitable for cutting thick wires close to the joint between the bar and the screw body.

Bars were then placed in a centralized position on a device with bilateral support, so that the distance between the supports could be set in 20 mm (Fig 1). Next, the device set was placed in the universal test machine Instron 4411, so that the chisel was placed equidistant from the supports (Fig 1A). To perform the test, the machine was programmed to displace 5 mm at a speed of 1 mm/min (Fig 1B). Maximum force (kgF) exerted to bend the screw bar in 5 mm was recorded and the bending resistance calculated by means of the following formula:

$$S = \frac{2.546473 \times F \times D}{T^3}$$

- » 2.546473= Constant for calculating the resistance of metal bars
- » S = Flexural strength (kgF)
- » F = Force (N)
- » D = Distance between the supports (mm)
- » T = Thickness of the wire (mm)

To evaluate modulus of elasticity, which was obtained from the tension x deformation graph of the materials (Figs 2, 3 and 4) during the flexural bending resistance test, Bluehill 2 (Instron Inc., version 2.17) test monitoring software was used. The modulus of elasticity represents the stiffness of the material to a certain deformation, within the elastic limit. Therefore, the greater is the modulus of elasticity, higher is the stiffness of the evaluated material. After test, data obtained were submitted to the one-way Analysis of Variance and the Tukey Test, with a level of significance of 5%.

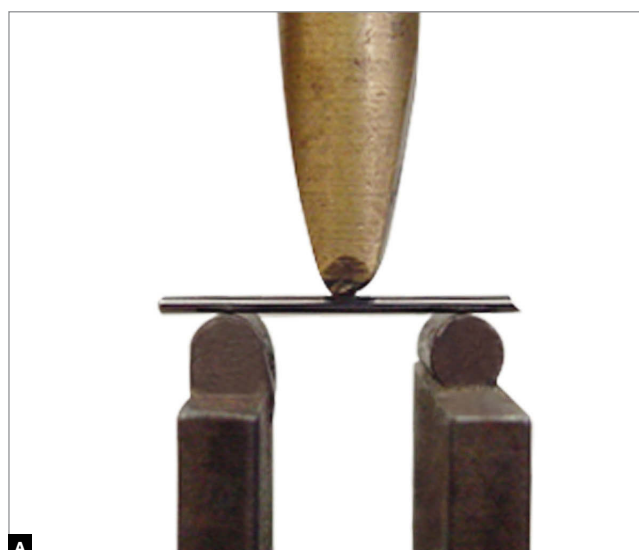


Figure 1 - *In vitro* evaluation of flexural strength of different brands of screw expanders. (A) The screw stem positioned before the test, (B) after flexural test.

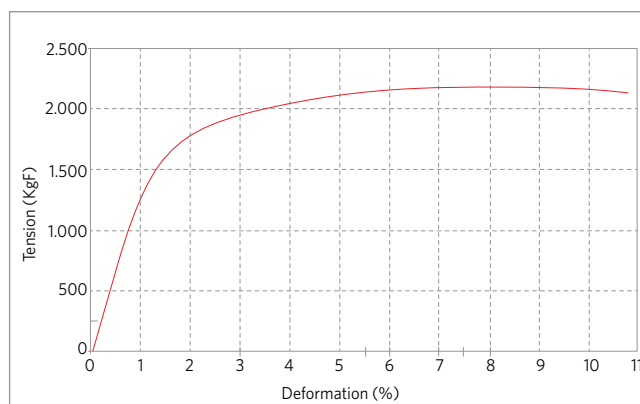


Figure 2 - Stress x deformation showing the flexural strength of Morelli screw.

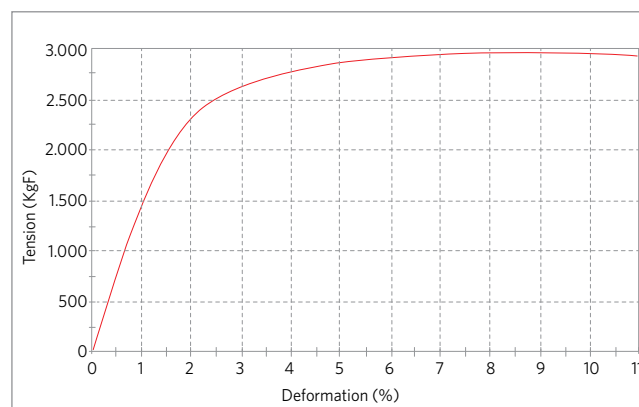


Figure 3 - Stress x deformation showing the flexural strength of the Forestadent screw.

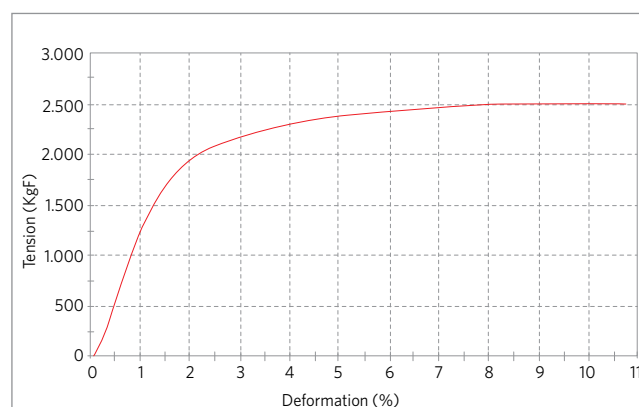


Figure 4 - Stress x strain showing the flexural strength of the Dentaurem screw.

RESULTS

The one-way Analysis of Variance showed that there was statistically significant difference among the evaluated screws ($p < 0.01$). The results described in Table 2 show that Forestadent screw presented the highest bending resistance, significantly higher than the value of Dentaurem screw, which was significantly higher than the obtained for that of Morelli screw ($p < 0.05$). The results of the modulus of elasticity showed that Forestadent screw had the greatest modulus of elasticity (154 GPa), followed by Dentaurem (140 GPa) and Morelli screw (136 GPa), (Table 2).

DISCUSSION

The mechanical properties are one of the most important characteristics of metals during the various applications. In orthodontic and orthopedic

Table 1 - Characteristics and brands of expansion screws analyzed.

Group	Commercial brand	Characteristics
Group 1	Morelli, Sorocaba, Brazil	Stainless steel. Expansion capability 12 mm.
Group 2	Dentaurum, Ispringen, Germany	Stainless steel. Expansion capability 12 mm. Stem diameter 1.45 mm.
Group 3	Forestadent, Pforzheim, Germany	Stainless steel. Expansion capability 12 mm. Stem diameter 1.45 mm.

Table 2 - Mean (standard deviation) of bending resistance of three points (MPa) and modulus of elasticity (GPa) of expansion screws of three brands evaluated: Morelli, Dentaurum and Forestadent.

Commercial brands	Bending resistance (MPa)		Modulus of elasticity (GPa)
Morelli	2370.38 (33,91)	C	136
Dentaurum	2517.75 (33,14)	B	140
Forestadent	3477.72 (79,48)	A	154

Different letters represent statistically significant difference ($p < 0.05\%$).

treatments, such as rapid maxillary expansion, the metal wires and expander screw are submitted to mechanical load that cause localized residual tensions, capable of causing permanent deformations. The material must have sufficient resistance to the stresses involved in the movements of the articulations and biocompatibility, without releasing toxic products into the oral environment.^{9,8} Characterization of the metal alloy and the expansion screw behavior is very important in order to know the real conditions, possibilities and limitations of use because screws are offered on the market by various manufacturers, frequently without adequate specification of properties.

Statistical analysis of data obtained in the mechanical flexural bending resistance tests showed that Forestadent screw showed a significantly higher bending resistance than Dentaurum screws.

Subsequently, Dentaurum screws presented a significantly higher value than the Morelli ones (Table 1). During activations, forces are generated with magnitudes ranging from 1000 to 3500 grams in a single activation and accumulate over 7000 grams during the consecutive activations.¹⁹ These results indicate the possibility of using Forestadent screws in clinical situations that may require greater expansion screw rigidity, such as rapid maxillary expansion performed in adult patients. The higher resistance values may be explained by the greater modulus of elasticity presented by this screw, making this material more resistant to deformation, leading to better force transmission to the sutures during screw activations in comparison with other screws. Moreover, the screws of the three tested brands can be used in all cases of rapid maxillary expansion. However, when greater resistance of the screw bars is required, the choice must be the most resistant one, that according to the present study is Forestadent followed by the Dentaurum and Morelli screws.

Rapid maxillary expansion provides heavy forces, above 450 N,^{13,14,19} which can easily open the median palatine suture in young patients.^{12,18} Therefore, the results of the flexural bending tests suggest that the expansion screws present suitable resistance for satisfactory rapid maxillary expansion procedure, without harm to the expansion screw and, obviously, not compromising the RME procedure.

CONCLUSIONS

The flexural bending resistance of the screws was influenced by the commercial brand. Among the manufacturers tested, Forestadent screw presented the highest bending resistance and modulus of elasticity, followed by Dentaurum and Morelli screws. The three screws presented adequate flexural bending resistance for use in rapid maxillary expansion procedures.

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Histomorphometric evaluation of periodontal compression and tension sides during orthodontic tooth movement in rats

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Objective: The purpose of this study was to evaluate the thickness of the periodontal ligament of rat molars during orthodontic tooth movement (OTM).

Methods: Thirty Wistar rats were divided into three groups of 10 animals each: GI, GII and GIII and the mice were euthanized at 7, 14 and 21 days, respectively. Experimental subjects were compared to their respective controls by the Mann-Whitney test. Comparison of values between compression and tension sides were performed during the same and different time periods through Analysis of Variance (ANOVA), Kruskal-Wallis test and, subsequently, Tukey's test.

Results: Groups GI and GII showed decreased PDL size in the apical regions of the mesiobuccal root and in the cervical region of the distobuccal root. There was also an increased PDL in the cervical regions of the mesiobuccal root, apical region of the distobuccal root and middle region of both roots.

Conclusion: The reduction and increase in PDL size were seen in the same root, which characterizes tooth inclination. The apical, middle and cervical regions were compared with one another in each time period and at three times: 7, 14 and 21 days. They were also compared in each region, confirming a tipping movement in GI and GII and a gradual decreased intensity between GI to GII, reaching normal dimension in GIII.

Keywords: Tooth movement. Periodontal ligament. Periodontium.

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INTRODUCTION

Histology is one of the areas of biology that has enabled numerous advances in Orthodontics, since it is a science that studies the microscopic structures of tissues and organs and is, therefore, intimately related to the study of tooth movement. Pioneer studies of Sandstedt,²⁴ Oppenheim,¹⁶ Reitna,¹⁹ Roberts,^{21,22} Rugh²³ and Davidovitch⁸ are classical and constitute the basis of orthodontic knowledge in this area.

The periodontal ligament (PDL), located between bone and tooth, is the physiological mediator of orthodontic treatment.⁸ This is a modified periosteum⁴ that is capable of causing tissue resorption and bone deposition.⁸ PDL cellular kinetics has provided information that defined the events of proliferation and differentiation of orthodontic reaction, essential for the mechanical induction of osteogenesis and osteoclasia.^{15,17,25,28,29}

Tooth displacement occurs in response to an induced force and comprises three elements: Initial stress, plateau and progressive tooth movement.²¹ In the first week, stress occurs through dental displacement in the PDL, bone resistance and extrusion.²² During this time, initial PDL stress varies according to PDL thickness, root length and periodontal health.²¹ Initial tooth displacement happens in seconds, but effective PDL compression requires one to three hours.²² One minute after application of continuous force to a murine first molar, there are changes in electrical potential of the periodontium, which in turn generate PDL osteogenic and osteoclastic responses²², in other words, force application triggers a cascade of cellular events in the PDL.⁸ Bone tissue is removed by osteoclasts and new bone is deposited by osteoblasts as periodontal structures adapt, keeping the teeth in their new environment.^{15,17,25,28,29}

Although histological changes in the periodontium associated with orthodontic induction of osteoclasia and osteogenesis^{15,17,25,28,29} and the phenomenon of bone bending²² are of common knowledge in the literature, little information is available concerning the histometric behavior of PDL compression and tension sides during tooth movement in different root regions and at different time periods. Such gap spurred authors to conduct this study, which aimed to assess the PDL thickness first molars of rats undergoing orthodontic tooth movement (OTM).

MATERIAL AND METHODS

Sample selection and distribution

Thirty 2.5 to 3-month-old male Wistar rats (*Rattus norvegicus*, albino), weighing between 250 and 350 g, were used in this experiment. The animals were provided by the Animal House of FOA-UNESP and were fed with ground feed (Produtor Activated Feed, Anderson & Clayton S.A., Laboratório Abbott do Brasil, São Paulo, Brazil) and water *ad libitum*.

The experimental models were divided into three groups, composed of 10 animals each:

- » Group I (GI): 7 days of OTM.
- » Group II (GII): 14 days of OTM.
- » Group III (GIII): 21 days of OTM.

In all 3 groups, the right upper first molars were subjected to OTM and the left upper first molars were used as controls.

Placement and activation of orthodontic devices

Before the experimental procedures, the animals were kept in cages for 7 days in a 12/12-hour cycle with constant temperature.

To place the mechanical device, the muscle relaxant Xylazine hydrochloride was used (Dopaser, Calier Laboratorios SA, Spain) at a ratio of 0.03 ml / 100 g body weight with the anesthetic ketamine hydrochloride (Vetaset, Fort Dodge Animal Health, Fort Dodge, Iowa, USA) at a ratio of 0.07 ml / 100g body weight. Both drugs were applied by intramuscular injection.

This research employed an orthodontic device designed by Heller and Nanda⁹ and modified by Conso-laro and Martins-Ortiz⁵ (Fig 1).

The device consisted of a 4 mm length stainless steel coil-spring (0.006 x 0.022 HI-TIITM, 3M Unitek, USA).⁵ In order to increase retention, 0.20 mm ligature wires (Morelli, Sorocaba, Brazil) were adapted to the molars and incisors and covered with chemically cured composite resin (Concise 3M Unitek, Sumaré, Brazil). The amount of activation was measured by means of a caliper until it was expanded to 6 mm,⁵ which is equivalent to 40cN¹² or 40 g of applied force. Force magnitude was set in advance by means of a 28-450 g tension gauge (Dentaurum, Germany). Due to continuous eruption of the rat incisors, the position of the ligature wires was evaluated on a weekly basis. There was no need for readjusting.

Euthanasia and specimen preparation

After 7 (GI), 14 (GII) and 21 (GIII) days, the animals were euthanized by overdose of anesthetic and then decapitated.²⁵ The right maxillary quadrant was used in the experimental group while the left maxillary quadrant was used as control.

Parafin-embedded samples were cut into serial sections of 6µm thickness, showing the mesiobuccal and distobuccal roots.⁹ The sections were made in the mesiodistal direction in the first upper molars, parallel to the long axis of the teeth for microscopic analysis in the furca region.⁵ Subsequently the material was stained with hematoxylin and eosin.

Scanning of histological sections

For histometric analysis, the most central section of each tooth was selected and captured using a digital camera (AxioCam MRc5, Carl Zeiss MicroImaging, GmbH, Germany) coupled to an optical microscope (Leitz GmbH Aristoplan, Germany) in a 4X objective using a software (Axio Vision 4.5, Carl Zeiss, Germany) installed on a computer.

Tracing

After scanning of the histological sections, tracing was performed on the roots to measure the PDL size in different regions (Fig 2).

The procedure was adapted from the method proposed by King.¹³

Line 1

Long axes of mesiobuccal and distobuccal roots in the image of the root canal.

Line 2

Perpendicular to the long axis of the root, in the most apical point of the tooth root, bounded by the tooth and bone surfaces. A modification of the method proposed by King, who advocated the use of the most apical point of the PDL.

Line 3

Perpendicular to the long axis of the root in the most cervical point of the inter-radicular alveolar bone crest, bounded by the tooth and bone surfaces.

Line 4

Perpendicular to the long axis of the root in the midpoint between lines 2 and 3, bounded by the tooth and bone surfaces.

Extensions of Lines 2, 3 and 4 over the PDL were histometrically analyzed by the ImageLab 2000 software (DiracomBio Informática Ltda., Vargem Grande

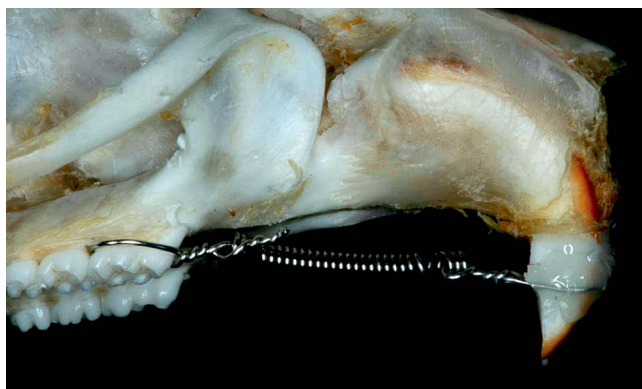


Figure 1 - Appliance inducing tooth movement.

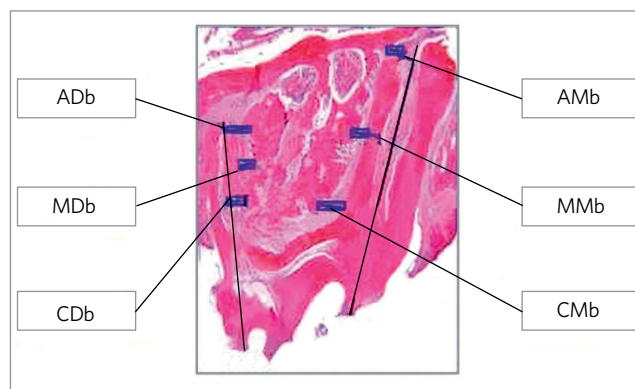


Figure 2 - Tracing of evaluated periodontal ligament regions: Apical distobuccal (ADb) middle distobuccal (MDb) and cervical distobuccal (CDb), apical mesiobuccal (AMb), middle mesiobuccal (MMb) and cervical mesiobuccal (CMb).

do Sul, Brazil), determining PL thickness in metric units at the apical, middle and cervical levels.

Measures evaluated

Linear measure terminology indicates the root in question, mesiobuccal (M) or distobuccal (D); the region evaluated, apical (Ap), middle (Md) or cervical (Ce); the time period in which the murine molar was submitted to OTM, 7 days (GI), 14 days (GII) and 21 days (GIII); and, additionally, the condition of the tooth being assessed, moved (m) or control (c) tooth.

STATISTICAL ANALYSIS

SigmaStat software (Advisory Statics for Scientists, version 3.1, SPSS, Chicago, USA) was utilized. The mean values of experimental groups GI, GII and GIII were compared with their respective controls by the Mann-Whitney test ($p < 0.05$). Comparisons between regions in the same period of time and in different time periods in the same region were performed by analysis of variance (ANOVA, Kruskal-Wallis – $p < 0.05$). When ANOVA detected a statistical difference, multiple comparisons were determined by Tukey's test.

METHOD ERROR

Method error was obtained by randomly selecting one of the roots in two groups. Measurements were performed twice by the same operator and at different periods.¹⁰ This repetition revealed the random error by the Dahlberg formula: $S_e^2 = \sum d^2 / 2n$, where S_e represents Dahlberg's error,⁷ $\sum d^2$ is the sum of squares of differences between the first and second measurements and $2n$ represents twice the number of cases that the measurements were repeated. To evaluate systematic error (bias), Mann-Whitney test was employed.¹⁰

RESULTS

Tables 1 and 2 show the method error. Probability and significance levels (P) correspond to the systematic error (bias),¹⁰ while the values obtained through Dahlberg's formula⁷ determine the random error. The method showed no systematic or random errors and provided results within acceptable parameters without compromising the reliability of the findings of this research.

Tables 3, 4 and 5 refer to GI, GII and GIII, respectively, and show a comparison between the experimental and control groups in each region (apical, middle or cervical) of the mesiobuccal or distobuccal roots.

There were statistically significant differences ($p < 0.05$) in the three regions of both roots in GI and GII (Tables 3 and 4), when comparisons were made between teeth that were either moved or not moved.

However, comparisons in GIII exhibited no statistically significant differences ($p < 0.05$) between moved and not-moved teeth in the three regions of both roots (Tables 3 and 4).

Tables 6 and 7 show a comparison between apical, middle and cervical measurements in the mesiobuccal and distobuccal roots, respectively in GI, GII or GIII.

The results showed significant differences between the apical region of the mesiobuccal root and the middle and cervical regions ($p < 0.05$) in GI and GII, which exhibited similar values (Table 6). A comparison between the apical, middle and cervical regions in GIII showed no statistically significant difference.

The data also revealed statistical differences between the cervical region of the mesiobuccal root and the middle and cervical regions ($p < 0.05$) in GI and GII, which exhibited statistically similar values (Table 6). A comparison between apical, middle and cervical regions in GIII showed no statistically significant difference.

Table 1 - Mean differences, t values (bias), probability and significance levels (p) and Dahlberg's random error obtained in GI.

Region / Time	Difference mean	t	p	Dahlberg
ADb7m	0.001	0.277	0.785	0.003872983
MDb7m	0.002	0.577	0.571	0.003162278
CDb7m	-0.003	-1.152	0.264	0.003872983
ADb7c	0.003	0.878	0.391	0.003872983
MDb7c	0.001	0.342	0.736	0.003872983
CDb7c	0.002	0.647	0.526	0.003162278

Table 2 - Mean differences, t values (bias), probability and significance levels (p) and Dahlberg's random error obtained in GIII.

Region / Time	Difference mean	t	p	Dahlberg
AMb21m	0.000	0.000	1.000	0.004472136
MMb21m	-0.001	-0.361	0.722	0.003872983
CMb21m	-0.0002	-0.0974	0.923	0.003193744
AMb21c	0.001	0.372	0.714	0.003872983
MMb21c	0.003	1.152	0.264	0.003872983
CMb21c	-0.001	-0.277	0.785	0.003872983

Table 3 - Means and standard deviations of different thicknesses of periodontal ligament of mesiobuccal (Mb) and distobuccal (Db) roots, moved teeth (m) and controls (c) in GI (7 days) in apical (A) middle (M) and cervical (C) regions, and probability and significance levels (p).

Periodontal ligament mesiobuccal root				Periodontal ligament distobuccal root			
Region / Time	Mean	Standard Deviation	p	Region / Time	Mean	Standard Deviation	p
AMb7m	0.109 (A)	0.00316	<0.001*	ADb7m	0.148 (A)	0.00789	<0.001*
AMb7c	0.127 (B)	0.00675		ADb7c	0.127 (B)	0.00675	
MMb7m	0.148 (A)	0.00789	<0.001*	MDb7m	0.146 (A)	0.00699	<0.001*
MMb7c	0.128 (B)	0.00632		MDb7c	0.128 (B)	0.00632	
CMb7m	0.149 (A)	0.00994	<0.001*	CDb7m	0.107 (A)	0.00483	<0.001*
CMb7c	0.128 (B)	0.00632		CDb7c	0.127 (B)	0.00675	

*Different letters: Statistically significant differences indicated by the Mann-Whitney test ($p < 0.05$).

Table 4 - Means and standard deviations of different thicknesses of periodontal ligament of mesiobuccal (Mb) and distobuccal (Db) roots, moved teeth (m) and controls (c) in GI (14 days) in apical (A) middle (M) and cervical (C) regions, and probability and significance levels (p).

Periodontal ligament mesiobuccal root				Periodontal ligament distobuccal root			
Region / Time	Mean	Standard Deviation	p	Region / Time	Mean	Standard Deviation	p
AMb14m	0.117 (A)	0.00483	<0.001*	ADb14m	0.139 (A)	0.00876	0.005*
AMb14c	0.128 (B)	0.00632		ADb14c	0.128 (B)	0.00632	
MMb14m	0.139 (A)	0.00876	0.005*	MDb14m	0.138 (A)	0.00789	0.004*
MMb14c	0.128 (B)	0.00632		MDb14c	0.127 (B)	0.00675	
CMb14m	0.140 (A)	0.00816	0.003*	CDb14m	0.116 (A)	0.00516	<0.001*
CMb14c	0.129 (B)	0.00568		CDb14c	0.128 (B)	0.00632	

*Different letters: Statistically significant differences indicated by the Mann-Whitney test ($p < 0.05$).

Table 5 - Means and standard deviations of different thicknesses of periodontal ligament of mesiobuccal (Mb) and distobuccal (Db) roots, moved teeth (m) and controls (c) in GI (21 days) in apical (A) middle (M) and cervical (C) regions, and probability and significance levels (p).

Periodontal ligament mesiobuccal root				Periodontal ligament distobuccal root			
Region / Time	Mean	Standard Deviation	p	Region / Time	Mean	Standard Deviation	p
AMb21m	0.127 (A)	0.00675	1.000	ADb21m	0.130 (A)	0.00667	0.500
AMb21c	0.127 (A)	0.00675		ADb21c	0.128 (A)	0.00632	
MMb21m	0.130 (A)	0.00667	0.500	MDb21m	0.129 (A)	0.00568	0.714
MMb21c	0.128 (A)	0.00632		MDb21c	0.128 (A)	0.00632	
CMb21m	0.131 (A)	0.00568	0.169	CDb21m	0.124 (A)	0.00516	0.054
CMb21c	0.127 (A)	0.00675		CDb21c	0.129 (A)	0.00568	

*Different letters: Statistically significant differences indicated by the Mann-Whitney test ($p < 0.05$).

Tables 8 and 9 show a comparison between apical, middle and cervical regions of the mesiobuccal and distobuccal roots, respectively in GI, GII and GIII. The only statistically significant difference ($p < 0.05$) was found between periods of 7 and 21 days in the apical, middle and cervical regions of the mesiobuccal and distobuccal roots.

DISCUSSION

Teeth can move physiologically or induced by mechanical load. Researches on this subject

report consistent opinions regarding biological results.^{15,17,19,21,22,23,25,28,29} The onset of biological changes occurs through the action of stimuli triggered by root displacement in the PDL space, thereby establishing areas of tension and compression.²¹ Roberts²² reported that maximum displacement of a rat first molar occurs in the PDL space after about three hours of movement induction. Subsequently, this stimulus triggers a series of events involving cellular differentiation and proliferation resulting in bone resorption and formation.^{8,15,17,25,28,29}

Table 6 - Significance of intragroup comparison between means of different thicknesses of periodontal ligament in apical (A), Medium (M) and cervical (C) regions of mesiobuccal root (Mb) of moved teeth (m) in GI or GII or GIII.

GI		GII		GIII	
Region / Time	Mean	Region / Time	Mean	Region / Time	Mean
AMb7m	0.109 (A)	AMb14m	0.117 (A)	AMb21m	0.127 (A)
MMb7m	0.148 (B)	MMb14m	0.139 (B)	MMb21m	0.130 (A)
CMb7m	0.149 (B)	CMb14m	0.140 (B)	CMb21m	0.131 (A)

*Different Letters: Statistically significant differences indicated by ANOVA, Kruskal-Wallis - $p < 0.05$ and subsequent application of Tukey's test for difference identification.

Table 8 - Significance of intergroup comparison between means of different thicknesses of periodontal ligament in apical (A), Medium (M) and cervical (C) regions of mesiobuccal root (Mb) of moved teeth (m) in GI or GII or GIII.

A		M		C	
Region / Time	Mean	Region / Time	Mean	Region / Time	Mean
AMb7m	0.109 (A)	MMb7m	0.148 (A)	CMb7m	0.149 (A)
AMb14m	0.117 (AB)	MMb14m	0.139 (AB)	CMb14m	0.140 (AB)
AMb21m	0.127 (B)	MMb21m	0.130 (B)	CMb21m	0.131 (B)

* Different Letters: Statistically significant differences indicated by ANOVA, Kruskal-Wallis - $p < 0.05$ and subsequent application of Tukey's test for difference identification.

The use of rats as an experimental framework over the years has enabled the solution of problems such as the lack of conclusive results involving clinical trials in humans.²⁰ Murine molars exhibit limited development⁵ so that the biological events that take place during OTM are very similar to those of humans but occur in a shorter period of time given these animals' accelerated metabolism.²⁰

Although aware of this biological factor characterized by greater speed in the metabolic reactions of rats,²⁰ which leads most researchers to use experimental times of 1, 3, 5 and 7 days, the authors of this study were interested in investigating the intensity of these reactions during the reactivation intervals applied to orthodontic appliances in humans, i.e., after at least 21 days following the application of force in order to add some new information to clinical practice.

Among the numerous limitations inherent in the histomorphometric technique, one should highlight the

Table 7 - Significance of intragroup comparison between means of different thicknesses of periodontal ligament in apical (A), Medium (M) and cervical (C) regions of distobuccal root (Mb) of moved teeth (m) in GI or GII or GIII.

GI		GII		GIII	
Region / Time	Mean	Region / Time	Mean	Region / Time	Mean
ADb7m	0.148 (A)	ADb14m	0.139 (A)	ADb21m	0.130 (A)
MDb7m	0.146 (A)	MDb14m	0.138 (A)	MDb21m	0.129 (A)
CDB7m	0.107 (B)	CDB14m	0.116 (B)	CDB21m	0.124 (A)

*Different Letters: Statistically significant differences indicated by ANOVA, Kruskal-Wallis - $p < 0.05$ and subsequent application of Tukey's test for difference identification.

Table 9 - Significance of intergroup comparison between means of different thicknesses of periodontal ligament in apical (A), Medium (M) and cervical (C) regions of mesiobuccal root (Mb) of moved teeth (m) in GI or GII or GIII.

A		M		C	
Region / Time	Mean	Region / Time	Mean	Region / Time	Mean
ADb7m	0.148 (A)	MDb7m	0.146 (A)	CDB7m	0.107 (A)
ADb14m	0.139 (AB)	MDb14m	0.138 (AB)	CDB14m	0.116 (AB)
ADb21m	0.130 (B)	MDb21m	0.129 (B)	CDB21m	0.124 (B)

* Different Letters: Statistically significant differences indicated by ANOVA, Kruskal-Wallis - $p < 0.05$ and subsequent application of Tukey's test for difference identification.

method of performing linear measurements on a large number of experimental models to obtain a mean value.

In this study, histometric analysis was performed in the longitudinal direction. To minimize the error potential described above, histological sections were obtained sequentially from 1 to 50. Slides of histological sections numbers 24, 25 and 26, which were expected to display a larger mesiodistal size, were analyzed and the one with the best image quality was selected for subsequent histomorphometric analysis.

However, it should be noted that analysis of a histological section, be it quantitatively or qualitatively, is limited to the image being analyzed and often overlooks information concerning other regions.

As there was negligible or no inflammatory influence in the region, periodontal spaces were used in the inter-radicular septal region, which corresponds to the distal surface of the mesiobuccal root and the mesial surface of the distobuccal root. This event takes

place in the mesial surface of the mesiobuccal root and distal surface of the distobuccal root and can lead to outcome interpretation errors.

The orthodontic force causes changes in the PDL, indicating that tooth movement has started.¹⁹ According to the literature, this force ranges between 10 g^{14,18} or even 30 g and 60 g.^{3,29,30} King et al¹² demonstrated no significant difference in the amount of OTM between 40 g and 60 g, and further concluded that orthodontic appliances can be overloaded without increasing the amount of OTM. Brudvik and Rygh³ linked this result with the presence of hyaline areas that delay bone remodeling. Thus, a force of 40 cN (equivalent to 40 g) was employed in this experiment.

Isaacson et al¹¹ pointed out that the unit of measure gram (g) is used to refer to mass and is therefore unsuitable to express force levels, which requires the use of the unit of measure Newton (N). The conversion factors are: 1 N = 101,937 g or 1 g = 0.00981 N. Whereas centi (c) is prepended to a unit of measure and forms the name of a derived unit 100 times smaller than the first, one can conclude that 1 g = 0.981 cN, or that 1 g corresponds to approximately 1 cN.

Ashizawa and Sahara¹ explained that in the early stages of OTM the magnitude of the initial force may not affect bone formation in the tension side but can influence the PDL condition on the compression side.

Measurements of PDL space in teeth undergoing OTM (GI, GII and GIII) were lower than in the control group and were construed as a state of PDL compression, while higher values indicated a PDL traction.

In this study, PDL width was approximately 0.13 mm in the apical, middle and cervical regions of murine molars not subjected to OTM, a value that proved similar to those observed in the literature.²⁷

A comparison between GI linear values and those of the control group showed an occurrence of statistically significant difference in the three regions of the two roots (Fig 3). Apical regions of the mesiobuccal root and cervical regions of the distobuccal root exhibited lower values than the control group, and probably experienced the phenomenon of compression of PDL fibers. Moreover, the cervical regions of the mesiobuccal root, apical regions of the distobuccal root and middle regions of the both roots displayed higher values than control group, and may be related to changes in PDL traction direction. It should be noted

that dimensional changes in OTM do not reflect the amount of tooth movement, highlighted by Baumrind² as ten times greater than changes in PDL width.

These dimensional changes caused by OTM are related to a biological response after application of mechanical forces. This clearly demonstrated that the use of the method devised by Heller and Nanda⁹ induced tooth inclination, as previously described by Talic et al,²⁶ since two completely distinct and opposed phenomena could be observed in the same root, be it mesiobuccal or distobuccal.

After 14 days of experiments, a statistically significant difference between GII and the control group continued to occur in the three regions of the two evaluated roots (Fig 4). The direction of the dimensional changes noted in GII remained the same as those observed in GI. However, change magnitude was lower in GII than in GI, i.e., the likelihood occurrence of PDL tension and compression sites was more pronounced at 7 days of OTM, a fact consistent with previous studies that explain the occurrence of tissue remodeling through alveolar bone resorption in the regions of compression and deposition of bone tissue in the portions where the PDL fibers were stretched, namely, in the tension areas.^{15,17,23,25,28,29}

A comparison between GIII and control group values showed a lack of statistically significant difference in the three regions of the two evaluated roots (Fig 5). This equivalence between values shows a total reestablishment of the integrity of the PDL 21 days after the probable compression in the apical region of the mesiobuccal root and in the cervical region of the distobuccal root; and tension in the PDL fibers of the middle areas of both roots, cervical areas of mesiobuccal roots and apical areas of distobuccal roots. This decrease in the intensity to a level not statistically different from the control group corroborates the literature, indicating that the support periodontium is the site where tissue modifications caused by OTM take place, which results in the distribution and dissipation of mechanical stress.^{4,8}

A comparison between the experimental groups whose teeth moved and the control group, whose teeth did not move in three different time periods, suggested the occurrence of alveolar bone remodeling and offered ideal conditions for observing morphological changes in PDL.¹⁴

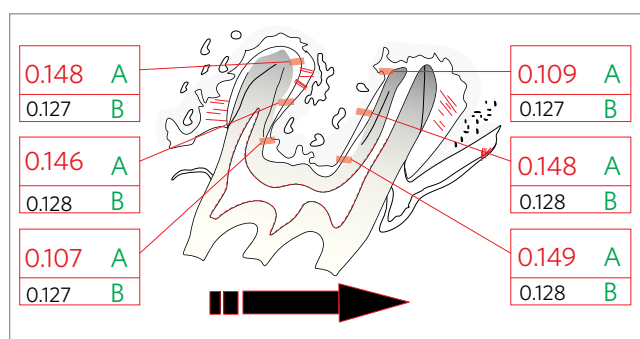


Figure 3 - Means of periodontal ligament dimensions in mesiobuccal and distobuccal roots in GI and Control Group.

* Different Letters: Statistically significant differences ($p < 0.05$)

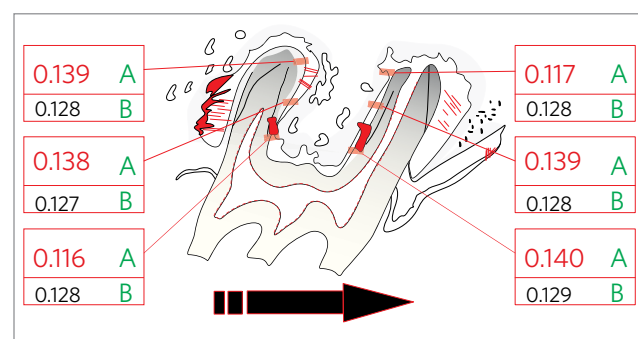


Figure 4 - Means of periodontal ligament dimensions in mesiobuccal and distobuccal roots in GII and Control Group.

* Different Letters: Statistically significant differences ($p < 0.05$)

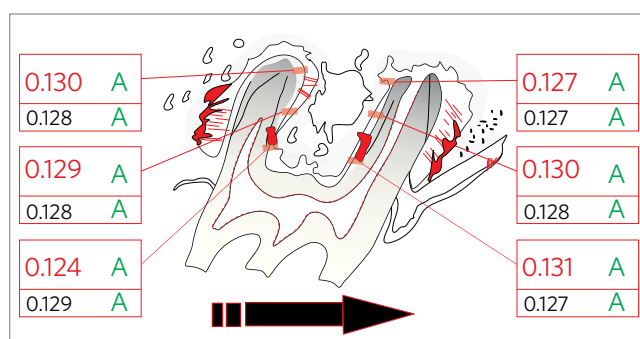


Figure 5 - Means of periodontal ligament dimensions in mesiobuccal and distobuccal roots in GIII and Control Group.

* Different Letters: Statistically significant differences ($p < 0.05$)

The following comparative analyses considered only teeth that experienced movement. Initially, PDL size values were compared in the three different regions, i.e., apical, middle and cervical of the same root, mesiobuccal or distobuccal, individually in GI, GII or GIII.

The mesiobuccal root exhibited a significant PDL size difference in the apical region relative to the middle and cervical portions 7 days and 14 days into the experiment (Fig 6). Conversely, the middle and cervical regions exhibited no significant difference. Data from GI and GII showed that the apical region of the mesiobuccal root experienced a different phenomenon which occurred in the middle and cervical regions.²⁶ Moreover, the magnitude of the changes in GI was higher than in GII. A comparison between the values obtained in the apical, middle and cervical regions in the mesiobuccal root of GIII showed statistical equivalence, suggesting that in the three regions

(regardless of the phenomenon mentioned before) PDL restored its dimensions, indicating that bone remodeling occurred^{15,17,23,25,28,29} after 21 days of OTM.

A comparison between the values obtained in the three different regions of the distobuccal roots in GI and GII showed a significant difference in the cervical region relative to the middle and apical portions (Fig 7). In contrast, comparative analysis between the apical and middle regions showed no significant difference. Data from GI and GII showed that the cervical region of the distobuccal root experienced a different phenomenon which occurred in the middle and cervical regions²⁶ and which allows one to assert that similarly to what had taken place in the mesiobuccal root the magnitude of the changes was higher in GI than in GII. A comparison between the three regions of the distobuccal roots in GIII showed no statistically significant differences. The PDL is the physiological mediator of orthodontic treatment, maintaining tooth positioning through the distribution of physiological and induced forces.^{1,15} In this sense, the histomorphometric data collected from GIII pointed to a likely restoration to normalcy in the three dimensional levels evaluated after 21 days into the experiment and confirmed PDL's role in the maintenance of periodontal homeostasis.

It is probable that the apical region of the mesiobuccal root and cervical region of the distobuccal root experienced PDL fiber compression. Moreover, the cervical regions of the mesiobuccal root, apical region of the distobuccal root and middle region of both roots may be related to PDL changes in the tension direction.

There was also concern in individually assessing changes in each region, be it the apical or middle or

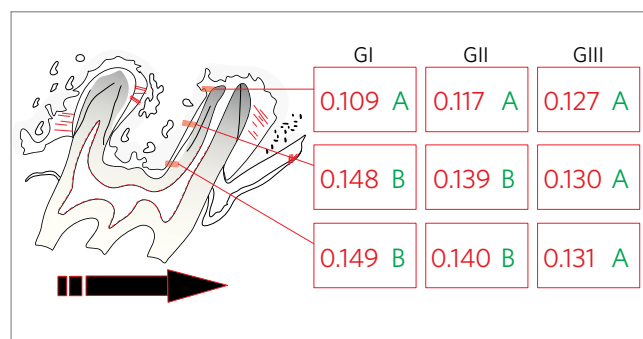


Figure 6 - Mean periodontal ligament dimensions in apical, middle and cervical regions of mesiobuccal root in GI or GII or GIII.

* Different Letters: Statistically significant differences ($p < 0.05$).

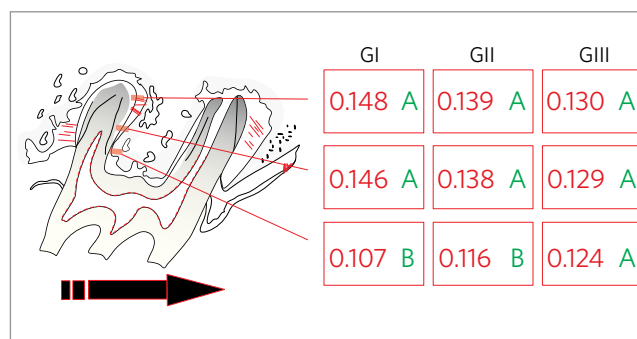


Figure 7 - Mean periodontal ligament dimensions in apical, middle and cervical regions of distobuccal root in GI or GII or GIII.

* Different Letters: Statistically significant differences ($p < 0.05$).

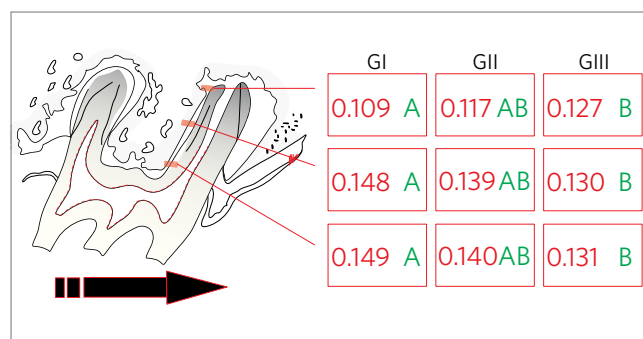


Figure 8 - Mean periodontal ligament dimensions in apical or middle or cervical regions of mesiobuccal root in GI, GII and GIII.

* Different Letters: Statistically significant differences ($p < 0.05$).

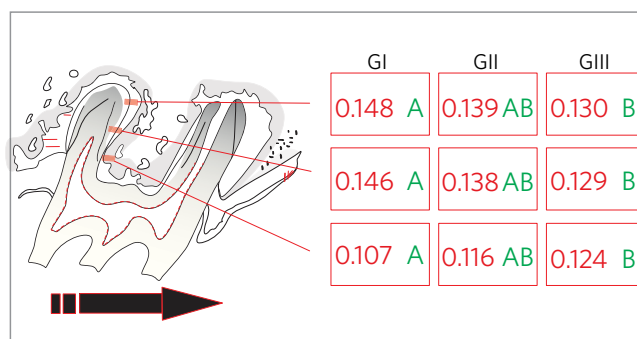


Figure 9 - Mean periodontal ligament dimensions in apical or middle or cervical regions of distobuccal root in GI, GII and GIII.

* Different Letters: Statistically significant differences ($p < 0.05$).

cervical in the mesiobuccal root (Fig 8) and distobuccal root (Fig 9) at three different times in groups GI, GII and GIII. These comparisons allowed equality between GI and GII values as well as between GII and GIII. The finding of a significant difference between GI and GII was noteworthy.

According to the literature, hyalinization in compression zones emerges at different times, depending on the intensity of the applied force.¹⁹ Its appearance has been reported to occur between three and six hours after force application,¹⁵ or else as a result of one day of tooth movement.³ The need to gradually remove this hyalinized²³ tissue starting on the seventh day of experiment should be underlined.²⁷ Cuoghi⁶ noted that in the first moments of OTM no change occurs in the microscopic morphology of the alveolar bone. OTM in the early stages is probably established at the expense of tooth displacement in the PDL and bone bending.

Figures 8 and 9 suggest that potential hyaline areas present in the GI were probably experiencing a recovery process in GII and were virtually eliminated in GIII. Although in the same root PDL showed dimensional changes in different directions, the gradual return of linear values to homeostasis occurred in all areas examined in both roots, regardless of increases or decreases in PDL size. The hypothesis of hyalinized zones developing in areas of traction has not been ruled out.

Tooth movement consists of mechanical loading over teeth based on biomechanical principles.⁸ Investigation of biological phenomena is prompted by the desire to expand knowledge of these events in order to determine whether clinical orthodontics is effective and harmless. Furthermore, this goal stems from a perpetual quest to improve the clinical protocol, generating knowledge of principles and biological changes in tissues, cells and molecules.²¹

All OTM knowledge attained in the early days,^{8,16,19,21-24} in conjunction with information generated through the analysis of qualitative changes in the PDL^{15,17,19,21,23,25,28,29} and the results provided by morphometric research, all contribute to continued advancement in this line of investigation.

CONCLUSIONS

After 7 days of OTM, PDL dimensions were reduced in the apical region of the mesiobuccal root and cervical region of the distobuccal root, and were enlarged in the cervical region of the mesiobuccal root, apical region of the distobuccal root and middle region of both roots.

This reduction and enlargement in PDL size was observed in the same root, either mesiobuccal or distobuccal, and is representative of tooth inclination.

PDL size changes improved after 14 days of OTM and recovered normal control group values after 21 days.

Apical, middle and cervical regions were compared with each other in both roots and confirmed the occurrence of lingual inclination at 7 and 14 days of the experiment.

Individual assessment of each region (middle, apical or cervical) in the three time periods, confirmed that PDL dimensions were gradually restored in both roots, i.e., mesiobuccal and distobuccal.

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Orthopedic treatment of Class III malocclusion with rapid maxillary expansion combined with a face mask: A cephalometric assessment of craniofacial growth patterns

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Objective: The aim of this prospective study was to assess potential changes in the cephalometric craniofacial growth pattern of 17 children presenting Angle Class III malocclusion treated with a Haas-type expander combined with a face mask.

Methods: Lateral cephalometric radiographs were taken at beginning (T_1) and immediately after removal of the appliances (T_2), average of 11 months of treatment. Linear and angular measurements were used to evaluate the cranial base, dentoskeletal changes and facial growth pattern.

Results: The length of the anterior cranial base experienced a reduction while the posterior cranial base assumed a more vertical position at T_1 . Some maxillary movement occurred, there was no rotation of the palatal plane, there was a slight clockwise rotation of the mandible, although not significant. The ANB angle increased, thereby improving the relationship between the jaws; dentoalveolar compensation was more evident in the lower incisors. Five out of 12 cases (29.41%) showed the following changes: In one case the pattern became more horizontal and in four cases more vertical.

Conclusions: It was concluded after a short-term assessment that treatment with rapid maxillary expansion (RME) associated with a face mask was effective in the correction of Class III malocclusion despite the changes in facial growth pattern observed in a few cases.

Keywords: Angle Class III malocclusion. Cephalometrics. Headgear appliances. Maxillary expansion.

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

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INTRODUCTION

Class III malocclusion defined as a facial skeletal discrepancy, may result from a variety of morphological combinations between maxilla and mandible, both in the sagittal direction (mandibular prognathism, maxillary retraction, or a combination thereof) and in the vertical direction (excess or decrease in lower anterior facial height).^{1,2,9,27,30}

It has been estimated that the prevalence of Class III malocclusion among Japanese and Chinese is around 14% of the population.¹⁹ In 1994, an epidemiological study conducted in the region of Bauru, Brazil, found that this malocclusion is prevalent in 3% of all patients assessed.²²

Before 1970, the orthodontic literature treated all Class III malocclusions as mandibular prognathism. Therefore, many authors were reluctant to discuss maxillary protraction as a viable treatment method, resorting only to the use of a chin cup to prevent mandibular growth.¹⁷

The finding that maxillary deficiency is often a component of skeletal Class III enhanced the potential of orthodontic-orthopedic treatment in promoting maxillary growth.^{3,5,6,18,27} However, by the time most of this growth is completed, treatment options become limited.^{1,4,13}

Angle Class III with maxillary deficiency, with a well positioned or retruded mandible and a reduced anterior facial height, provides the best treatment prognosis.^{13,16,27,28} It should be emphasized, however, that this does not mean that one should not tackle Angle Class III with maxillary deficiency and mild mandibular prognathism.²⁸

Early orthodontic-orthopedic therapy has proven effective from a skeletal standpoint, thus favouring the establishment of growth patterns and normal relationships between facial components.^{1,3,23} Although still controversial,^{7,20} rapid maxillary expansion (RME) combined with reverse pull maxillary headgear may be beneficial in early treatment of Class III malocclusion, even in the absence of posterior crossbite^{4,13,19,23,27}. RME might disarticulate the maxilla and trigger cellular responses in the sutures, thereby strengthening the effects of maxillary protraction.^{13,27}

The purpose of this study was to evaluate potential changes in craniofacial growth pattern by

means of lateral radiographs in Class III children treated with RME and face mask.

MATERIAL AND METHODS

Material

This prospective study involved 17 Brazilian children with mixed dentition (7 male and 10 female), mean age 8 years and 7 months $\pm$ 1 year and 8 months (ranging from 6 years and 1 month to 11 years old), who were treated with a Haas-type expander combined with a Petit face mask to correct Class III malocclusion.

The patients presented the following characteristics:

- 1 – Angle Class III malocclusion.
- 2 – A facial Class III pattern due to maxillary deficiency, mandibular excess or a combination of both factors.
- 3 – Mixed dentition stage.
- 4 – Good oral health.

This study was approved by the Ethics Committee of Santa Cecilia.

Methods

All patients were treated with a modified Haas-type expander⁸ (Fig 1) and followed a protocol comprising one full turn on the first day and a half turn in the subsequent days until overcorrection of the case. In order to facilitate intraoral elastic placement, the hooks of the expander were positioned between the canines and first molars, in a horizontal direction parallel to the occlusal plane.^{11,27} After screw fixation, a Petit face mask (Orthosource, Brazil) was placed with initial force of 350 grams (Fig 2), ultimately reaching 500 grams on each side. The patients were instructed to wear the mask for at least 14 hours/day.¹² The mean treatment time with the face mask was 11 months $\pm$ 3 months (ranging from 6 to 18 months).

Patients were evaluated using lateral cephalometric radiographs at the beginning of treatment (T_1) and immediately after removal of the appliances, with a mean treatment time of 11 months (T_2). The lateral cephalometric radiographs were performed in the same cephalostat, using Ortophos unit (Siemens, Germany) laterally and in centric occlusion. Cephalograms were traced over the radiographs

using acetate paper. All anatomical details of interest to this study were highlighted and the variables were measured with a cephalometric protractor (Desetec) and a millimeter ruler (Desetec) with subdivisions of 0.5° and 0.5 mm, respectively. The following cephalometric variables were used:

1. Linear Variables (Fig 3): S-N, S-Ar, Ar-Goc, Me-Goc, S-Goc, N-Me, S-Gnc, N-Goc, Co-A, Co-Gn and ANS-Me.
2. Angular Variables (Fig 4): Sella angle, articulare angle, gonial angle, superior gonial angle, inferior gonial angle, SNA, SNB, 1.PP, IMPA, SN.PP angle.

The quotient of Siriawat and Jarabak²⁵ was used to describe facial morphology: The ratio between the posterior facial height (S-Goc) and the anterior facial height (N-Me) multiplied by one hundred (100). Any percentage lower than 59% was classified as a hyperdivergent growth pattern, between

59 and 63% a neutral pattern, and above 63% a hypodivergent pattern (Fig 3).

Statistical Method

To assess data normality, the Kolmogorov Smirnov test was initially applied. After verifying that the distribution of the measured values was symmetrical, the parametric test (t-test) was employed to evaluate potential differences between the linear and angular measures studied at T_1 and T_2 . A 5% significance level was used.

Method Error

To assess method accuracy, radiographs of nine patients from the study sample ($n = 17$) were randomly selected. All radiographs were traced and measured again by a single operator after a period of one month counted from the original tracing. The paired t-test was applied to evaluate

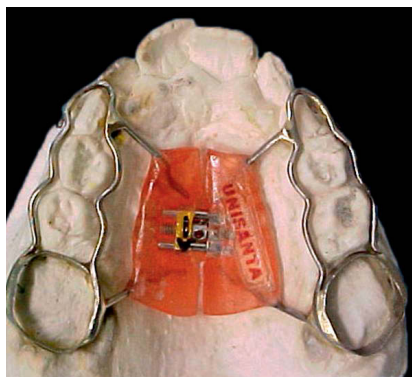


Figure 1 - Modified Haas-type expander.

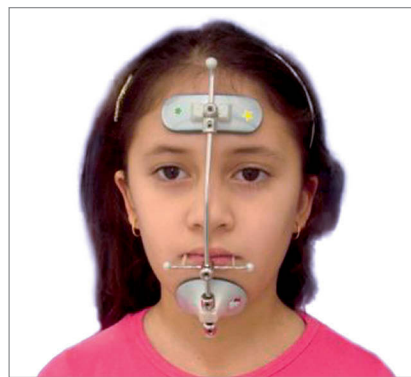
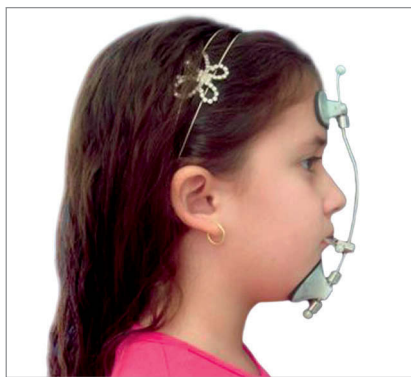


Figure 2 - Frontal and lateral facial photographs with Petit face mask.

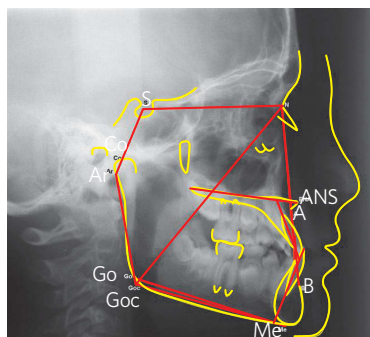


Figure 3 - Linear cephalometric variables.

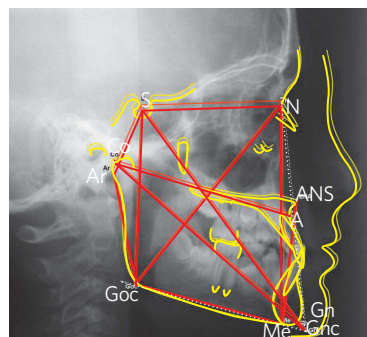


Figure 4 - Angular cephalometric variables.

systematic error. Once the difference between the first and second measurements had been obtained for each cephalogram, Dahlberg's formula was applied to estimate random error.

RESULTS

All cases evolved into a Class I correction or a class II overcorrection. Systematic error (bias) was not significant in any of the cases. Random error is depicted in Tables 1 and 2. Ar-Goc was the only linear cephalometric variable that showed no statistically significant difference between T_1 and T_2 (Table 1). Among the angular variables, the superior and inferior Gonial angles SNA, ANB and IMPA showed statistically significant differences between T_1 and T_2 . In the remaining angular measures no significant changes occurred (Table 2).

At T_1 , 9 cases showed hypodivergent patterns (52.94%), 5 cases neutral patterns (29.41%) and 3

cases hyperdivergent patterns (17.64%). In 12 cases (70.58%) there were no changes in facial pattern between T_1 and T_2 . In 5 cases (29.41%) the following changes occurred: Case 2 displayed a hyperdivergent pattern, which became neutral, 2 cases (3 and 8) exhibited neutral patterns, which became hyperdivergent, and 2 cases (10 and 17) had hypodivergent patterns which ultimately became neutral.

DISCUSSION

Given the difficulty of restraining the mandibular growth and the plasticity of the maxillary growth, the combination of RME and reverse pull maxillary headgear is a treatment protocol often used in the correction of Angle Class III malocclusion.^{3,6,13,18,21,27} Prognosis of this type of malocclusion will depend on variables such as etiology and location of the skeletal problem.⁴ In this study, patients were clinically evaluated and facially classified as

Table 1 - Mean and standard deviation (SD) of linear cephalometric measurements (in mm) and random error at T_1 and T_2 .

		Significance		Random error	
		T_1	T_2	(p)	T_1 T_2
S-N	Mean	65.12	65.97	**	0.22 0.43
	s.d.	3.46	3.40		
S-Ar	Mean	29.79	30.97	**	0.47 0.33
	s.d.	3.18	2.99		
Ar-Goc	Mean	40.50	41.09	0.157	0.72 0.33
	s.d.	5.25	6.09		
Goc-Me	Mean	65.03	66.82	**	0.71 1.10
	s.d.	5.32	4.69		
S-Goc	Mean	67.29	68.94	**	0.63 0.56
	s.d.	6.36	7.16		
N-Me	Mean	106.06	109.94	**	0.47 0.57
	s.d.	5.78	5.98		
S-Gnc	Mean	120.29	123.24	**	0.48 0.40
	s.d.	6.28	6.70		
N-Goc	Mean	102.21	105.18	**	0.43 0.85
	s.d.	8.18	8.09		
Co-A	Mean	79.68	80.85	**	0.53 0.75
	s.d.	5.92	5.83		
Co-Gn	Mean	105.68	107.97	**	0.67 0.70
	s.d.	7.18	7.47		
ANS-Me	Mean	61.74	64.15	**	0.38 0.70
	s.d.	3.07	3.31		

Table 2 - Mean and standard deviation (SD) of angular cephalometric measurements (in degrees) and random error at T_1 and T_2 .

		Significance		Random error	
		T_1	T_2	(p)	T_1 T_2
Å.Sella	Mean	119.26	119.53	0.484	0.89 0.53
	s.d.	5.76	5.85		
Å. Articulare	Mean	147.62	149.09	0.076	1.14 1.04
	s.d.	6.27	6.55		
Å. Gonial	Mean	127.27	127.09	0.608	0.47 0.81
	s.d.	5.27	5.38		
Å Sup.Gon.	Mean	52.06	51.12	0.033*	0.60 0.70
	s.d.	3.09	3.02		
Å. Inf.Gon.	Mean	75.21	75.97	0.043*	0.45 0.60
	s.d.	3.95	4.14		
SNA	Mean	82.82	83.62	0.002*	0.18 0.87
	s.d.	4.58	4.79		
SNB	Mean	81.35	80.74	0.108	0.35 0.50
	s.d.	4.63	4.91		
ANB	Mean	1.47	2.88	**	0.25 0.79
	s.d.	2.27	2.10		
1.PP	Mean	111.18	111.62	0.554	0.98 1.40
	s.d.	6.25	7.17		
IMPA	Mean	85.79	84.79	0.039*	0.59 0.74
	s.d.	7.08	7.38		
SN.PP	Mean	4.65	4.94	0.478	1.03 1.24
	s.d.	3.94	3.50		

Class III due to maxillary deficiency, mandibular excess or a combination of both factors. The magnitude of skeletal discrepancy was not taken into account as it can be seen in the wide variability exhibited by the ANB angle at T_1 (mean 1.470 ± 2.270).

The present study combined prior expansion with maxillary traction based on the fact that protraction in combination with an initial period of expansion may yield more significant skeletal results^{7,13,18,27} even though expansion produces undesirable dentoalveolar side effects, such as mandibular rotation.¹⁶ On the other hand, studies showed that RME does not influence the correction of Class III with a face mask.^{7,20}

A meta-analysis¹³ of clinical studies that used face masks was undertaken to determine the most convenient time to employ this treatment method. The authors found major orthopedic alterations in younger patients. In summary, maxillary protraction may be effective during the period in which the maxillary sutures are still open. Major orthopedic changes can be achieved and retained in permanent dentition as long as the face mask treatment happens in the deciduous or early mixed dentition.³⁰ In this study the average chronological age of patients was 8 years and 7 months (ranging from 6 years and 1 month to 11 years old at T_1).

Although the treatment goal when using a face mask is to displace the maxilla forward by applying force to the circum-maxillary sutures, there are skeletal and dental changes with forward displacement of the maxilla (1-3 mm),^{2,19} maxillary incisors flaring, downward and backward mandibular rotation and, finally, lingual inclination of mandibular incisors.^{2,5,9,19,29} The orthopedic alterations are responsible for 75% of the correction (25% dental) with maxillary advancement representing 75% of the skeletal correction (25% due to downward and backward mandibular rotation).²⁷ In comparison with the average, the results of this research are in agreement with other findings in the literature. There was an anterior displacement of the maxilla and the mean value of the SNB angle decreased, although this reduction was not statistically significant, suggesting that the downward and backward mandibular rotation increased the ANB angle. Interestingly, although the gonial angle did not

change, the upper and lower gonial angles changed significantly. This is due to the tendency of the mandible to rotate clockwise.

The patients in this study did not show any maxillary rotation. The direction of the force produced by the mask was more horizontal and parallel to the occlusal plane.^{11,27} The literature shows a high incidence of anterior movement without rotation.³ The earlier the therapy is started the greater is the anterior displacement due to the release of the pterygomaxillary fissure.²

The anterior and posterior vertical dimensions of the face increased significantly between T_1 and T_2 . When patients were evaluated separately, they showed no facial patterns changes between T_1 and T_2 in 12 cases (70.5%). The changes followed a more vertical pattern. In four out of five cases (29.4%) whose facial patterns experienced modifications. In only one case there was a more horizontal pattern. Increases were found in all linear values, although they were not significant at the level of the ramus. Angular measurements tended to worsen in the vertical direction. Overall, the changes may be considered minimal in the vertical plane, with stability occurring in the facial growth pattern²⁵ in 70.5% of the cases.

It is noteworthy that at T_1 , 9 cases showed hypodivergent patterns (52.94%), 5 cases neutral patterns (29.41%) and 3 cases hyperdivergent patterns (17.64%). Thus, regarding the absence of the palatal plane rotation, it can be speculated that most patients exhibited horizontal growth patterns, which helped to preserve the facial pattern.

Dentoalveolar compensation had a bearing on the process of malocclusion correction, although only the lower incisors changed significantly between T_1 and T_2 . A non-significant change was found in upper incisor inclination, which may have been due to expansion in all cases, with a consequent compensation caused by the uprighing of these teeth. A marked variability was observed in treatment time (6 to 18 months) with this type of protocol, which can be ascribed to the severity of the malocclusion at T_1 and patient cooperation in wearing the face mask.

Regarding to the anterior cranial base (S-N) and the length of the mandibular body (Goc-Me), the ratio is 1:1 at age 11 years, according to Jara-bak.²⁶ The mean value of the anterior cranial base

(S-N) is 71 ± 3 mm. The patients in this study had an average chronological age of 8 years and 7 months with an average size of the anterior cranial base of 65.12 mm at T_1 . These results were in agreement with the findings of Jarabak, who noted a decreased anterior cranial base in subjects with skeletal Class III malocclusion. According to Jarabak²⁶ the length of the mandibular body at that same age (11 years) is 71 ± 5 mm. A difference between 0 and 5 mm in favor of the anterior cranial base is usually found in prepubertal ages. The mandibular body, therefore, is 5 mm shorter than the anterior cranial base in 8-year-old children. In this study, the subjects displayed a mean value of 65.03 mm of mandibular length at T_1 , therefore nearly the same size as the anterior cranial base, which characterized a Class III malocclusion. At T_2 , the average size of the anterior cranial base was 65.97 mm, showing an increase of 0.85 mm compared to T_1 and growing less than 1 mm, what is considered the average standard for a 1-year assessment.²⁶ In patients with a ratio of 1:1 (Goc-Me and S-N) at age 11 years the annual increment in mandibular growth is 1.5 mm per year, reaching 2 mm in Class III malocclusions. In this study, a mean increase of 1.8 mm was noted in the mandibular length between T_1 and T_2 , showing increased mandibular growth.

According to Björk,²⁶ the sella angle (Ar.S.N.) displays a mean value of $123 \pm 6^\circ$. The present study found a mean value of 119.26° at T_1 and 119.53° at T_2 , whereas no significant change was noticed during treatment. A smaller angle lower than the norm, or a closed angle, indicates a more vertical position of the posterior cranial base (S-Ar). With growth, this

situation tends to favor the anterior projection of the mandible, usually found in Class III malocclusions and skeletal deep bite.

The clinical outcomes showed that malocclusions were overcorrected in compliant patients, achieving in some cases a Class II of 3 to 4 mm. A longitudinal follow-up of the treated cases is warranted before stability of the results can be ascertained. The long-term treatment prognosis of Angle's Class III malocclusions tends to be better if the malocclusion is caused by maxillary deficiency rather than by mandibular prognathism.²⁸ New treatment protocols are emerging for maxillary traction and research should be conducted alternating rapid expansion and constriction of the maxilla, where previous studies^{14,15} reported an average protraction of 5.8 mm at point A. It was conducted a study²⁴ using anchorage implants in the search for a device capable of providing an extremely stable and secure anchorage in maxillary orthopedic treatments. A discrete anterior displacement of the jaw has also emerged as an alternative treatment. Osseointegrated mini-implants have emerged which can also be used as anchorage for maxillary protraction.²⁰ Thus, in a short term, alternative evidence-based treatment protocols will afford more efficient orthopedic corrections that minimizes undesirable side effects.

CONCLUSIONS

After a short-term assessment, it was concluded that treatment with RME combined with a face mask was effective in the correction of Class III malocclusion, leading to changes in the facial growth pattern in a few cases.

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Evaluation of the position of lower incisors in the mandibular symphysis of individuals with Class II malocclusion and Pattern II profiles

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Objectives: This study evaluated the position of mandibular incisors in the mandibular symphysis of individuals with Class II malocclusion and Pattern II profiles.

Methods: The sample consisted of 40 Caucasian patients (20 male and 20 female) with Class II malocclusion and Pattern II profile from 10 to 18 years of age (mean age of 12.84 years) who were selected from the records of the School of Dentistry of Universidade de Passo Fundo, Brazil. The linear cephalometric measurements used in this study were Ricketts' 1- AP, Interlandi's line I and Vigorito's 1-VT; and the angular measurement studied was the mandibular plane angle (IMPA).

Results: Mandibular incisors of individuals with Class II malocclusion and Pattern II profile tended to be buccally inclined and protruded.

Keywords: Diagnosis. Angle Class II malocclusion. Cranial circumference.

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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

Morphological facial analysis is the main diagnostic resource to determine facial patterns, which may be classified as Pattern I, II or III, short face or long face.^{9,18} Individuals with a Pattern II face are characterized by the positive sagittal discrepancy between maxilla and mandible,^{9,18} and their facial characteristics are correlated with the two variables that determine classifications: the maxillary protrusion and mandibular deficiency. In most individuals Pattern II is defined by mandibular deficiency.^{6,9,14}

An important characteristic of Pattern II is the position of mandibular incisors, which are a matter of concern due to their supposedly great importance in facial esthetics and in the stability of results after orthodontic treatments.^{3,5,8,15,19,23,26,27} So far, the parameters often used to evaluate the correct position of the mandibular incisors are cephalometric measurements, which associate these teeth with lines and planes that vary according to each author. These measurements have been defined for individuals with normal occlusion and harmonious faces, and, in most studies, no data for Brazilians have been included.^{13,19,23,26}

The stability of orthodontic treatment results should be improved if the orthodontist respects the morphology and functional characteristics of each individual.¹³ Individual variations, besides other factors, doesn't allow isolated fixed cephalometric goals due to the existing integration between facial and cranial structures. Therefore, individuals and their malocclusions can't all be treated by placing their mandibular incisors in the same position within basal bone.²⁷

Dentoalveolar compensations should be mentioned as well, which are spontaneous changes in incisor position and inclination trying to achieve a good occlusion anteriorly and an acceptable anterior guidance in cases of sagittal skeletal disharmony. Therefore, compensation is the reverse of skeletal disharmony. In general, mandibular incisors play a more important role in compensations than maxillary incisors.^{4,8,9} For different anteroposterior relations of the apical bases, nature provides different compensatory inclinations of maxillary and mandibular incisors to ensure occlusion harmony.²⁵

When in malocclusion, mandibular incisors are in a position of equilibrium and as teeth are moved, another position of equilibrium should be sought.

Therefore, anatomic, functional, cephalometric, periodontal and esthetic characteristics should be evaluated since they are the factors that limit incisor position.²⁸ Buccal and lingual cortical bone are the anatomic limits for the movement of the incisors and, consequently, the limits of orthodontic treatment.¹²

Few papers have studied individual tooth inclinations in order to evaluate differences between normal occlusions in different ethnic groups and populations or to investigate torques and angles prescribed by different authors.¹⁰

This study evaluated the inclination of mandibular incisors of untreated individuals with Class II malocclusion and Pattern II profile in order to analyze their position and to discuss the possibilities of determining goals for their movement.

MATERIAL AND METHODS

The sample consisted of 40 Caucasian patients (20 male and 20 female) with a Class II malocclusion and a Pattern II profile with ages from 10 to 18 years (mean age 12.84 years) who were selected from the records of the School of Dentistry of Universidade de Passo Fundo, Brazil. The study was approved by the ethics committee of the same university (CEP 065/2006). The sample was selected according to profile and facial photographs and according to prior clinical examination. The facial photographs were taken using a Nikon Digital SLR camera at 6.1 effective mega pixels, 6.24 total mega pixels, Nikon DX format. Patients had not undergone orthodontic or orthopedic treatment and did not have any syndrome.

Lateral cephalometric radiographs were acquired at the Radiology Service of the School of Dentistry of Universidade de Passo Fundo using an Orthophos 5 cephalometer (OrthophosPlus, Siemens, Germany). Radiographies were scanned and analyzed using the Radiocef Studio 2 software according to the manufacturer's instructions. To obtain the cephalometric measures, cephalometric landmarks were defined by one single examiner.

The cephalometric measurements used in this study were:

» Linear: Ricketts' I-AP, Interlandi's line I, Vigorito's I-VT.

» Angular: Incisor mandibular plane angle (IMPA).

Results were statistically analyzed. Means, medians and standard deviations were calculated, as well as minimum and maximum values of all variables under study. To check differences between genders, Student's t test for independent data was used and the level of significance was set at 5%.

RESULTS

Tooth relations to their apical bases

Means, medians, standard deviations, minimum

and maximum values of the measurements studied are shown in Table 1.

According to Table 1, the mean value of mandibular incisor in relation to Ricketts' AP line was 2.69 mm, and the standard deviation was 3.28. Most values in our sample were greater than the norm prescribed by the author.

The results of IMPA, whose mean was $95.7 \pm 5.83^\circ$, revealed that these teeth clearly tended to be in similar position or more proclined than



Figure 1 - Face and profile photographs of a Pattern II patient included in the study.



Figure 2 - Intraoral photographs of a Class II patient included in the study.



Figure 3 - Intraoral occlusal photographs of a Class II patient included in the study.

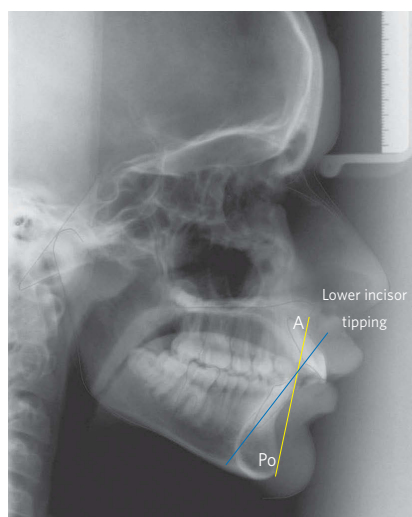


Figure 4 - Ricketts' 1-AP measurement.

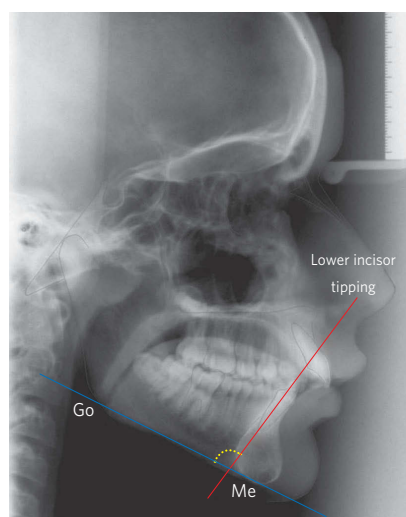


Figure 5 - IMPA measurement.

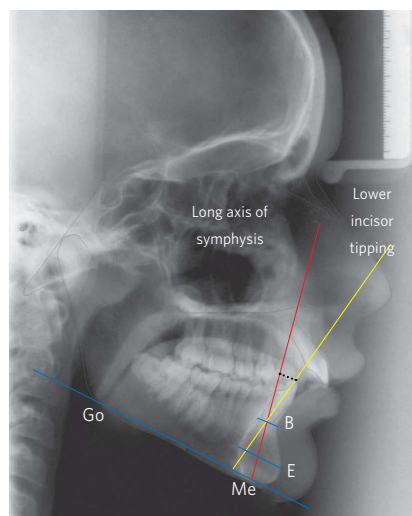


Figure 6 - Vigorito's 1-VT measurement.

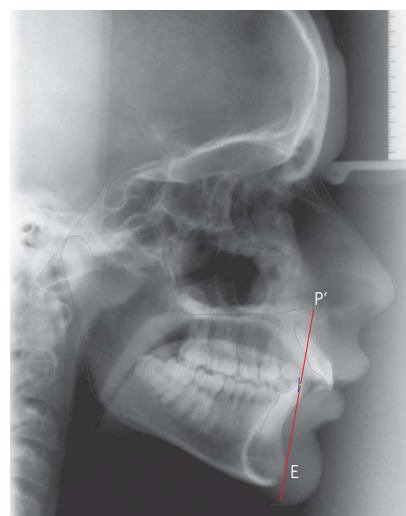


Figure 7 - Interlandi's line I measurement.

the normal mean and most of the sample had values above the mean.

Interlandi's I line in the sample had a mean value of -3.69 ± 2.99 mm, as seen in Table 1, indicating that incisors were more protruded than in individuals with normal occlusion. The other measure assessed, Vigorito's 1-VT, had a mean value of 7.40 ± 2.74 mm, which described the incisors' proclination.

Table 2 shows the comparison of the variables studied for both gender. According to results, there were no differences between genders.

DISCUSSION

Patients with a Pattern II profile are those that, through morphological facial analysis, have a positive sagittal relationship between the maxilla and the mandible, or a convex profile and other consequent changes.^{9,18} The individuals included in this study had a Pattern II profile and a Class II dental relationship.

According to our objectives, results were first compared with those obtained from a sample of white individuals with normal occlusion in the same area (Passo Fundo, Brazil). Second, comparisons

Table 1 - Cephalometric measurements of the sample.

	Mean	Median	Standard Deviation	Minimum Value	Maximum Value
Ricketts' 1-AP (mm)	2.69	3.01	3.28	-3.16	11.85
IMPA (degrees)	95.70	95.96	5.83	85.41	109.98
Interlandi's I line (mm)	-3.69	-4.20	2.99	-10.05	1.52
Vigorito's 1-VT (mm)	7.40	6.95	2.74	0.2	16.25

Table 2 - Comparison of cephalometric measurements between genders.

	Mean female gender	Standard Deviation	Mean male gender	Standard Deviation	Student's t test	p
Ricketts' 1-AP (mm)	3.04	3.63	2.32	2.94	0.4911	> 0.05*
IMPA (degrees)	96.04	6.30	95.37	5.46	0.7208	> 0.05*
Interlandi's I line (mm)	-3.75	3.24	-3.63	2.81	0.9012	> 0.05*
Vigorito's 1-VT (mm)	7.14	2.69	7.65	2.83	0.5679	> 0.05*

*No statistical difference.

were made with findings of studies that evaluated patients with a Class II molar relationship and the norms established by their authors.

Table 2 shows the comparison of the cephalometric variables for both genders. There were no differences between genders, confirming findings by Vale and Martins,²⁴ Aramaki et al,² Woitchunas,²⁸ Tukan,²² and Reis et al.¹⁷ Therefore, gender was not included in the discussion.

The mean value of the relation of the mandibular incisor to Ricketts' AP line was 2.69 ± 3.28 mm; ranging from -3.16 mm to 11.85 mm. Ricketts studied normal occlusion and found a mean value of 0.5 ± 2.5 mm and a forward inclination of the A-Pogonion plane in individuals with greater facial convexity, and a compensatory inclination of mandibular incisors in the same direction, with the opposite seen in straighter profiles.²⁰ Woitchunas, in a study conducted in Passo Fundo, Brazil, selected a sample of Caucasian individuals with normal occlusion and found a similar mean of 2.41 ± 1.68 mm compared to our findings, even though only patients with a Pattern II facial profile were enrolled. Therefore, in the samples with a Pattern II facial profile and with normal occlusion, in the same geographic area, incisors were protruded and different from those reported by Ricketts.¹⁹ Data found in our study showed that incisors were more protruded than in the sample studied by McNamara Jr.,¹⁴ who found a mean value of 1.3 ± 2.5 mm for patients with Class II, and by Vale

and Martins,²⁴ who evaluated Brazilians of Mediterranean descent with Class II, division I malocclusion and found a mean value of 1.70 ± 3.21 mm for males and 1.48 ± 2.85 mm for females.

The mean value of the relation of the mandibular incisors to Interlandi's I line was -3.69 ± 2.99 mm; ranging from -10.05 mm to 1.52 mm. The value defining normal occlusion was 0 mm.¹³ In 2002, Interlandi referred to a study that included individuals with excellent occlusion and profiles with normal characteristics and found a mean I line value of -1.28 mm, ranging from 0.50 mm to -2.50 mm. Woitchunas²⁷ found that I line had a mean value of -2.96 ± 2.96 mm in individuals with normal occlusion. The individuals with a Pattern II profile in our study had more protruded incisors in relation to Interlandi's I line than individuals with normal occlusion, but the similarity already demonstrated for 1-AP in the sample of individuals with normal occlusion in the same region was also found in our study.

The mean value of IMPA was $95.70 \pm 5.83^\circ$; ranging from 85.41 to 109.98°. According to Tweed,²³ the value for individuals with normal occlusion is 90°. Aramaki et al² evaluated Caucasian Brazilians with a Class II, division 1 malocclusion and found a mean value of $99.4 \pm 6.0^\circ$ before treatment with extractions, and $99.6 \pm 5.8^\circ$ for the group to be treated without extractions. Tukan²² conducted a study on Brazilians with a Class II, division 1 malocclusion and found that IMPA was $94.38 \pm 6.90^\circ$.

These values were similar to ours; and Aramaki et al² found that incisors were more proclined. This sample was probably composed of individuals with maxillomandibular discrepancies more severe than those in our study.

The analysis of IMPA, a measure universally adopted to characterize AP position of mandibular incisors, revealed that in our sample these teeth clearly tended to have values that are equal to or greater than those considered to be the normal. The lower limit of the standard deviation was 89.97, a close value to the mean prescribed by Tweed. Therefore, a large number of the individuals in our sample had values above the mean. It is easy to understand these high IMPA values in this sample, and the reason why some individuals had the minimum value should be investigated. One possible explanation may be associated with maxillary protrusion in the Pattern II group, a limitation or a barrier to the compensatory proclination of mandibular incisors.⁹ This fact should be elucidated in future studies.

The mean value of 1-VT was 7.40 ± 2.74 mm, ranging from 0.2 mm to 16.25 mm. The value prescribed by Vigorito was 6 mm,²⁷ found in a study of Caucasian individuals with normal occlusion. Woitchunas found a mean value of 6.17 ± 1.36 mm in normal occlusions, ranging from 2.00 to 9.00 mm. As for the minimum IMPA values, 1-VT values should be evaluated to improve the definition of the characteristics of the sample. These values show that incisors were more proclined in patients with Pattern II profile, which is fully compatible to the contemporary concepts that guide orthodontic practices.

A broader view of these results and comparisons suggests that individuals with Pattern II profiles tend to have a greater mandibular incisor proclination than those with a Class II malocclusion because the first always have a skeletal discrepancy in the maxillomandibular relationship, whereas the latter often have only a dental discrepancy that is responsible for the Class II relationship. Finally, 30% of all Class II do not correlate with a sagittal discrepancy between maxilla and mandible.¹⁸ Therefore, Class II malocclusions with Pattern II profiles demand dental compensation,

often explicit by the proclination of incisors, which are not necessarily the case in Class II.

In contrast, the fact that two groups of individuals in the same geographic region, one with normal occlusion²⁸ and the other with Class II malocclusions and Pattern II profiles have the same tendency to more proclination of incisors confirms the fact that compensation may be successful, resulting in normal occlusion. In the regular sample, there were some with a moderately increased maxillomandibular discrepancy who had enough and efficient compensation to determine normal relationships. Again, when compensation is successful, occlusion is normal. The offices of orthodontists are full of individuals treated by compensations who have normal occlusion.

The comparisons of the mandibular incisor position in this study sample and other norms described for the Brazilian population show that only I line had clinically significant differences.¹³ Although the mean value is higher, the difference is smaller when compared with the means of 1-VT.²⁷ This may reflect characteristic of the measure itself rather than a sample characteristic. The method to define I line is very similar to that used for 1-AP, and both show similar and greater discrepancies between values found for the position of mandibular incisors among individuals with a Pattern II profile.

CONCLUSIONS

The results of this study suggest that mandibular incisors of individuals with Class II malocclusion and Pattern II facial profiles are proclined.

The comparisons of the mandibular incisor position in the Brazilian population show that IMPA values for most of the sample are equal to or greater than the value prescribed by Tweed.²³ Ricketts' 1-AP measurements show that incisors are protruded in our sample in relation to the mean prescribed by Ricketts.²⁰ For the Brazilian population, only I line has clinically significant differences.¹³

Therefore, it seems that whenever the treatment of Class II malocclusions in individuals with a Pattern II facial profile is compensatory, treatment goals should include a more proclination of mandibular incisors.

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Assessment of facial profile changes in Class I biprotrusion adolescent subjects submitted to orthodontic treatment with extractions of four premolars

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Objective: To evaluate cephalometric changes in tooth and profile position in young adolescent individuals with Class I biprotrusion submitted to orthodontic treatment with extractions of four first premolars.

Methods: Pre and posttreatment lateral cephalometric radiographs from 20 patients with Class I biprotrusion malocclusion were used to evaluate the following measurements: nasolabial angle, distance from lips to E line, distance from lips, incisors, tip of the nose and soft tissue pogonion to Sy line.

Results: All measurements showed significant changes after treatment ($p < 0.05$), except the distance from lips and soft tissue pogonion to Sy line. There was a positive correlation between the retraction of incisors and the change of upper and lower lips ($0.803/0.925$; $p < 0.001$).

Conclusion: The profile retrusion observed occurred more due to nose growth than to lips retraction. The response from soft tissues to incisors retraction showed a great variability.

Keywords: Class I Angle malocclusion. Dental extraction. Dental esthetics. Facial profile.

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INTRODUCTION

More and more facial esthetics have been a concern for patients and professionals, while soft tissues have been increasingly emphasized on the orthodontic diagnostic methods. Facial harmony is included in the main objectives of orthodontic treatment, once the correct positioning of teeth over the basal bone may alter the profile, including the upper and lower lips position, the nasolabial and the labiomental angles.

Numerous factors are able to influence the changes that the soft tissues may suffer as a consequence of retraction or protrusion movements made on incisors, such as soft tissues morphology, thickness, tonicity and muscular pattern of the patient.^{6,14}

Among the individuals which complain over unpleasant facial esthetics and search orthodontists with the main objective of regaining balance on their facial profile, are those which show biprotrusion, a condition where upper and lower anterior teeth are protruded, creating a convex profile and difficulty in sealing the lips.

The correction of biprotrusion is frequently obtained through the extraction of four first premolars and retraction of anterior teeth with maximum anchorage avoiding mesial movement of the posterior teeth. This conduct may result in lip retraction, in an improvement of esthetics and of the lip seal due to an enhanced harmony and balance between skeletal, dental and soft tissues structures.

On the other hand, the follow-up of growing patients show that the normal maturation process associated with continuous mandibular growth and nasal development promote alone an enhancement on the profile, independent of extractions.²⁰ This maturation tends to continue after adolescence, resulting on an increase of this relative lip retraction.

Therefore, the objective of the present study was to assess changes in tooth position and in profile due to orthodontic treatment and facial growth of adolescent Class I biprotrusive patients treated with extraction of four first premolars.

MATERIAL AND METHODS

Material

Pre and posttreatment cephalometric lateral radiographs from adolescents submitted to orthodontic treatment in the Post-Graduation course

in Orthodontics of the Federal University of Rio de Janeiro (UERJ) were assessed. All radiographs were taken in the Department of Pathology and Oral Diagnosis of the School of Dentistry of the UERJ. Among the radiographs evaluated, 20 individuals (5 boys and 15 girls) were selected. Their mean age was 12 years and 4 months at the beginning of treatment, and 17 years by the end of treatment. The inclusion criteria were the following: a) Class I skeletal pattern (ANB angle between 0 and 4°), b) Class I malocclusion with biprotrusion, c) permanent dentition, d) no dental agenesis, e) treatment plan including four first premolars extraction, f) interincisal angle lower than 131°, g) I-NA angle higher than 22°, h) I-NB angle higher than 25°, i) I-NA distance greater than or equal to 5 mm, j) I-NB distance greater than or equal to 5 mm, k) no previous orthodontic treatment, l) individuals under 15 years of age at the beginning of treatment. Orthodontic treatment was standardized with fixed appliances, Edgewise standard system, with extraction of the four first pre-molars, followed by lower and upper canine and incisive retraction.

Methods

Pre (T_1) and post-treatment (T_2) cephalometric radiographs of each patient were traced by a single operator. The cephalometric points used in this research are identified in Figure 1. In order to confirm if the cases selected fulfilled the inclusion criteria, the following planes and lines were traced: N-A, N-B, upper incisor long axis and lower incisor long axis. Measurements from Steiner's analysis were also calculated: ANB angle, interincisal angle, I-NA angle, I-NB angle, I-NA distance and I-NB distance. Three lines were constructed for data collecting: a) Sx (horizontal reference line), traced 7° clockwise from SN line, registered at S point; b) Sy (vertical reference line), perpendicular to Sx, registered at S point; c) Ricketts' E line, line connecting Prn and Pog' points. The comparison between pre-treatment and post-treatment profiles, as well as the assessment of nose and chin growth in the facial profile were made through the following measurements: nasolabial angle (Prn-Sn-Ls), E-Ls distance, E-Li distance, Sy-Ls distance, Sy-Li distance, Sy-Is distance, Sy-Ii distance, Sy-Prn distance, Sy-Pog' distance. All measurements were

performed by a single operator and 40% of them (16 randomly chosen radiographs) were repeated after a month for error analyses.

Statistical analysis

Intraclass correlation coefficient analysis was performed to assess measurement errors and

descriptive analysis of data was performed, including mean, standard deviation and median of all variables. After normal distribution was confirmed through the Kolmogorov-Smirnov test, pre and post-treatment measurements were compared through a paired t test. Spearman test was applied to assess correlations among the measurements. The level of significance of 0.05 was adopted for all tests. The software used in the statistical analyses was the SPSS Statistics version 17.0.

RESULTS

The intraclass correlation coefficient was 0.99 and the measurements performed were considered reliable. Descriptive data for each measurement and the results from the paired t test are depicted in Table 1. Only the position of upper and lower lip and of soft tissue pogonion in relation to the Sy line did not show significant changes with treatment. The results obtained in the analysis of correlations among the cephalometric measurements observed by the Spearman test are shown in Table 2.

DISCUSSION

Extractions on orthodontic treatment are still a motive for debates and controversies, even though there is a consensus about the need to position teeth

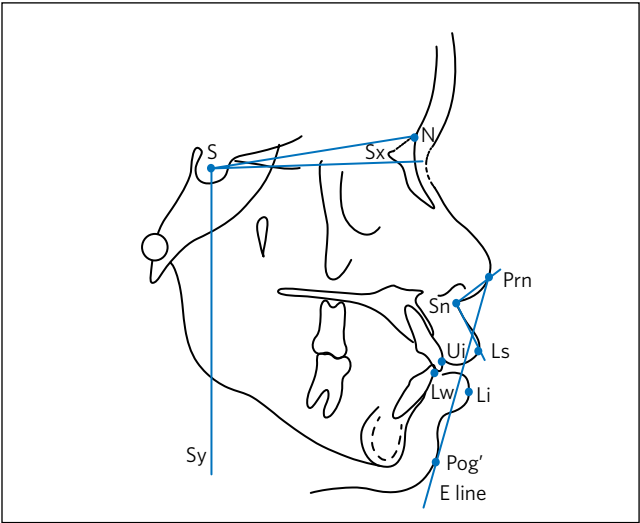


Figure 1 - Points used: S (Sella), N (Nasion), Ls (Labrale superius), Li (Labrale inferius), Ui (Upper incisor), Lw (Lower incisor), Prn (Pronasale), Sn (Subnasale), Pog' (Soft tissue pogonion). Lines used: Sx (horizontal reference line, traced 7° clockwise from the SN line, registered at S), Sy (vertical reference line, perpendicular to the Sx line, registered at S), Ricketts' E line (Prn-Pog').

Table 1 - Comparison between pre and posttreatment mean values of the measurements taken through a paired t test.

Measurements	Pre-treatment (t ₁)		Post-treatment (t ₂)		Change (t ₂ - t ₁)		p
	Mean	sd	Mean	sd	Mean	sd	
Nasolabial angle (degree)	101.0	12.28	104.8	10.07	3.8	7.27	0.030*
E-Ls (mm)	-0.9	1.87	-4.1	2.47	-3.2	2.08	0.000*
E-Li (mm)	2.0	2.16	-1.6	2.20	-3.6	1.95	0.000*
Sy-Ls (mm)	88.1	4.16	88.0	3.82	-0.1	3.48	0.899
Sy-Li (mm)	86.0	4.88	85.4	3.84	-0.6	4.46	0.539
Sy-Is (mm)	77.0	3.73	73.9	3.84	-3.1	2.92	0.000*
Sy-li (mm)	72.5	5.01	70.9	3.93	-1.6	3.65	0.043*
Sy-Pnr (mm)	98.2	4.92	102.1	5.28	3.9	4.57	0.001*
Sy-Pog' (mm)	75.4	5.60	77.3	5.30	1.9	4.93	0.102

*Statistically significant difference (p<0.05).
sd - standard deviation.

Table 2 - Correlation between the mean difference of pre and post-treatment cephalometric measurements through the Spearman analysis.

		Nasolabial	E-Ls	E-Li	Sy-Ls	Sy-Li	Sy-Ui	Sy-Lw	Sy-Pnr	Sy-Pog'
Nasolabial angle	Corr. coef.	1	0.020	-0.351	-0.201	-0.249	0.068	-0.099	-0.036	-0.125
	Sig. (P)		0.935	0.129	0.396	0.289	0.776	0.677	0.881	0.600
E-Ls	Corr. coef.	0.020	1	0.573	-0.225	-0.461	-0.222	-0.318	-0.567	-0.506
	Sig. (P)	0.935		0.008*	0.341	0.041*	0.347	0.172	0.009*	0.023*
E-Li	Corr. coef.	-0.351	0.573	1	0.161	0.018	0.050	0.060	-0.284	-0.186
	Sig. (P)	0.129	0.008*		0.497	0.939	0.834	0.803	0.225	0.432
Sy-Ls	Corr. coef.	-0.201	-0.225	0.161	1	0.907	0.803	0.946	0.797	0.752
	Sig. (P)	0.396	0.341	0.497		0.000*	0.000*	0.000*	0.000*	0.000*
Sy-Li	Corr. coef.	-0.249	0.461	0.018	0.907	1	0.817	0.925	0.829	0.917
	Sig. (P)	0.289	0.041*	0.939	0.000*		0.000*	0.000*	0.000*	0.000*
Sy-Ui	Corr. coef.	0.068	-0.222	0.050	0.803	0.817	1	0.854	0.621	0.753
	Sig. (P)	0.776	0.347	0.834	0.000*	0.000*		0.000*	0.003*	0.000*
Sy-Lw	Corr. coef.	-0.099	-0.318	0.060	0.946	0.925	0.854	1	0.839	0.788
	Sig. (P)	0.677	0.172	0.803	0.000*	0.000*	0.000*		0.000*	0.000*
Sy-Pnr	Corr. coef.	-0.036	-0.567	-0.284	0.797	0.829	0.621	0.839	1	0.736
	Sig. (P)	0.881	0.009*	0.225	0.000*	0.000*	0.003*	0.000*		0.000*
Sy-Pog'	Corr. coef.	-0.125	-0.506	-0.186	0.752	0.917	0.753	0.788	0.736	1
	Sig. (P)	0.600	0.023*	0.432	0.000*	0.000*	0.000*	0.000*	0.000*	

*Significant correlation ($p < 0.05$).

over their basal bone. Biprotusive individuals who have a Class I malocclusion many times search professionals spontaneously, unsatisfied with their facial esthetics and difficulty to seal lips. In these specific cases, one of the solutions is the treatment with extractions of the four first premolars and retraction of anterior teeth. Tweed¹⁸ already asserted in 1966 that he had observed a better balance and harmony of facial lines, stability of dentition, healthy oral tissues and an efficient masticatory system when their patients had their incisors well positioned over the basal bone at the end of treatment. He also noticed that the lack of facial harmony occurred in a direct proportion with the degree of projection of the dentition. Thus, the present study aimed to cephalometrically assess the dental and facial profile changes in 20 biprotusive adolescents with Class I malocclusion submitted to treatment with extraction of four first premolars and retraction of anterior teeth.

There are still doubts about the influence that the orthodontic treatment and craniofacial growth have on the results obtained by treatment of patients during their growth. Therefore, frequently almost all merits are attributed to the orthodontic therapy,

when growth has had a fundamental role in changes. Erdinc et al⁶ reported that many authors did not eliminate the effect of growth in facial changes observed with treatment, once it is difficult to separate the effects of growth and therapy. In order to answer these questions, this study made an effort to observe changes that could be attributed to growth or to orthodontic therapy.

The measurement of horizontal changes in dental and skeletal structures and in soft tissues was performed related to a reference line perpendicular to the Sx line, which is traced 7° clockwise from the S-N line. This method has already been validated in scientific literature^{9,10,14,17} and it was used in order to facilitate the comparison among the studies.

After establishing the necessary references and method the results were obtained and discussed with the pertinent literature. Initially, they showed that the upper incisors were retracted a mean of 3.1 mm and the lower incisors a mean of 1.6 mm in relation to the Sy line, similarly to the study of Oliveira et al.¹⁴

The difference in the nasolabial angle found in this research was similar to the one found by Bravo.⁴ The change in the nasolabial angle was significant;

this change, however, showed no positive correlations with any other measurement taken. This is probably due to the great individual variance, as other studies reported.^{4,10} According to Lai et al¹¹ and Oliveira et al,¹⁴ the variations in the response of the soft tissues are very extensive and difficult to predict or correlate in a perfect way to dental changes.

The changes in the upper and lower lips in relation to E line was very similar to the amount observed by Bravo.⁴ The change in the upper lip in relation to the E line, which was significant and evidences the retraction of the profile, could not be correlated to the change in the position of the upper incisor, but showed a significant correlation with the growth of the nose and of the soft pogonion. As the change in the upper lip in relation to the Sy line was not significant, it can be suggested that the profile changes were probably more due to the growth of the nose and chin than to the retraction of lips. The change of the lower lip in relation to the E line was significant, showing the retraction of the profile, but it could not be correlated to the position change of the lower incisor or to the nose and chin growth.

In a similar way, other studies^{11,17,20} showed that mandibular growth and nasal growth contribute further to the flattening of the profile than the retraction of lips. Ricketts¹⁵ observed a growth of the tip of the nose of about 1 mm/year in relation to the anterior nasal spine in growing patients. He claims that the nasal and mandibular growth associated to the retraction of teeth was responsible for esthetic changes often observed in the treated cases. Anderson et al¹ noted a greater flattening of the profile after the orthodontic treatment due to an additional growth of nose and chin during maturation of the studied individuals. Bishara et al³ emphasized that the movement of the tip of the nose in an anterior and inferior direction during growing, as it is greater than the displacement of the point A and of the upper lip, makes the nose more prominent. They also suggest that the treatment planning of growing patients must take into account that future changes may affect the profile in an adverse way. Erdinc et al⁶ observed a significant growth of the nose in patients treated with and without extraction of four first pre-molars. Halazone-tis⁸ noted a relative increase in the nose and chin in both genders in patients with similar age.

Additionally, it is important to consider that the soft tissues of nose and chin still growing in the adulthood, which may lead to a greater retrusion of the profile. Variations in gender have been reported in the literature. Formby et al⁷ evaluated lateral radiographs of 24 male and 23 female subjects, from 18 to 42 years of age and observed a greater flattening of the profile in male individuals, which presented a greater increase in the dimensions of the nose and in the width of the soft tissue in the region of the pogonion, similarly to the findings of Nanda et al¹² in 17 male and 23 female subjects, from 7 to 18 years of age. In the female gender, lips did not appear to be retruded because despite the increase in the dimensions of the nose, the width of the soft tissue in the region of pogonion decreased in women. In the present study it was not possible to make that comparison, as there were too few male patients.

As to the facial esthetics, it is important to emphasize that it is questionable whether the esthetic facial models from the past are still applicable to the faces considered esthetic today.¹³ There is a current tendency to value profiles with more prominent lips. Nguyen and Turley¹³ observed that the ideal Caucasian male profile has changed significantly across time and nowadays more projected lips with a greater exposure of lip vermilion are considered more attractive. Similarly, Yehezkel and Turley¹⁹ described a current tendency to adopt esthetic patterns with fuller and more anteriorly positioned lips in the Afro-American female profile, and this change occurred along the twentieth century. Auger and Turley² showed that patterns for an esthetic profile in Caucasian women also tend to adopt fuller and more anteriorly positioned lips. Scott et al¹⁶ noted that thicker vermilion borders were considered more attractive. Coleman et al⁵ reported in a study about the influence of the prominence of the chin in the esthetic preference of labial profile, that fuller anterior lips in relation to the Ricketts E line were generally preferred in extreme retrognathic and prognathic profiles, while retracted lips were preferred for more regular profiles. Thus, it is important to consider this tendency in the planning and performance of treatment in biprotrusion cases, and the orthodontist must avoid a flattening of the profile.

A positive correlation between upper lip retraction and the retraction of upper and lower incisor

was observed in the present study. The same correlation was observed for the lower lip retraction. These data confirm that the retraction of anterior teeth influences the lips position, although the difference between pre and post-treatment measurements of the position of the lips in relation to the Sy line was not significant. These results were similar to other studies.^{1,9,10} However, there is still discordance about the response from the soft tissues to the dental changes and in the alveolar process.⁶ According to Lai et al,¹¹ the attempts to establish a mean rate to detect a tendency or predict the response of soft tissues to the incisors movement were not well-succeeded due to the large variability of soft tissues among individuals.

CONCLUSIONS

The results from the present study lead to the following conclusions:

1. Nasolabial angle presented a significant in-

crease with treatment, which could not be correlated to any measurement assessed.

2. Upper and lower lips presented an increased distance to Ricketts' E line by the end of treatment, showing a retrusion in the profile. However, there was just a small variation between pre and post-treatment measurements of the position of lips in relation to the Sy line. Therefore, it is suggested that the change in the lips in relation to the E line is due more to the growth of nose and chin than to a real change in their position.
3. Upper and lower incisors were significantly retracted. This retraction was positively correlated to the change in the lips position. Although the change in the profile is attributed in great part to growth, the retraction of the incisors influenced the retraction of lips and thus the changes in the profile.

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Compensatory treatment of Angle Class III malocclusion with anterior open bite and mandibular asymmetry

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Class III malocclusion is characterized by anterior posterior dental disharmony, either with or without skeletal discrepancies. Facial esthetics may be compromised to a greater or lesser degree, depending on the magnitude of the discrepancy, and is one of the main factors motivating individuals to seek orthodontic treatment. In adult patients, therapy may be performed by means of dental compensation, in simpler cases, or in more severe situations, by means of association between Orthodontics and Orthognathic Surgery. The present article is a clinical case report of a patient with a vertical facial pattern, Angle Class III malocclusion, with open bite and important facial asymmetry. The patient was treated in a compensatory manner with extractions, using extra-oral appliances on the mandibular arch with high pull, applying the principles of the Tweed-Merrifield technique. This case was presented to the Brazilian Board of Orthodontics and Facial Orthopedics (BBO) as part of the requisites for becoming a BBO Diplomat.

Keywords: Facial asymmetry. Orthodontics. Angle Class III malocclusion.

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HISTORY AND ETIOLOGY

The patient presented for initial exam at the age of 20 years, in a good state of general health. She had no abnormal pressure habit and the main complaint was related to the presence of open bite in the anterior region and facial asymmetry with mandibular deviation to the right side. The patient appeared to be concerned about facial esthetics, by virtue of the asymmetry caused by laterognathism (Fig 1). On a more detailed examination of the occlusion, true mandibular deviation to the left was found, probably generated by asymmetrical growth and not by a purely functional deviation. Although the mother did not report any family history of Class III, the peculiarities involved pointed towards a multifactorial etiology.

DIAGNOSIS

Regarding to facial characteristics, the patient presented a dolichocephalic facial type, with convex profile, slightly increased lower facial third, labial competence and presence of asymmetry due to mandibular deviation to the left side. The lips were protruded, and the bottom lip was slightly forward to the upper lip (Fig 1).

With regard to the dental aspect, the patient presented Angle Class III malocclusion, anterior open bite, overjet of 1 mm with projected mandibular and maxillary incisors, characterizing dentoalveolar double protrusion. In addition the maxillary arch was found to be atresic with slight anterior crowding and rotation of teeth 15 and 25. The lower midline had a 2.5 mm deviation to the left side, but was coincident



Figure 1 - Initial facial and intraoral photographs.

with the center of the chin, characterizing a skeletal and not a dental deviation (Figs 1, 2).

The analysis of panoramic radiograph showed no significant alteration that would contraindicate performing orthodontic treatment (Fig 3). Cephalometric evaluation indicated important skeletal disharmony, with ANB equal to -2° ($SNA=78^\circ$ and $SNB=80^\circ$), poor mandibular growth in the vertical direction ($SN-GoGn=39^\circ$) denoting the vertical aspect of the face. Maxilla and mandible were shown to be slightly retracted in relation to the cranial base. These observations may be better evaluated in Fig 4 and Table 1.

TREATMENT OBJECTIVES

In the maxilla, to promote transverse expansion with the aim of improving arch shape. Perform extraction of teeth 15 and 25, with the objective of simultaneously provide anchorage loss and incisors retraction, thus establishing key relation of occlusion between first molars and closure of open bite in the anterior region, respectively.

In the mandible, to promote efficient anchorage and vertical control as tooth 43 is moved in the distal direction, the midline is corrected and the incisors are retracted after extraction of teeth 34 and 44. Thereby, significant improvement in the dental pattern was

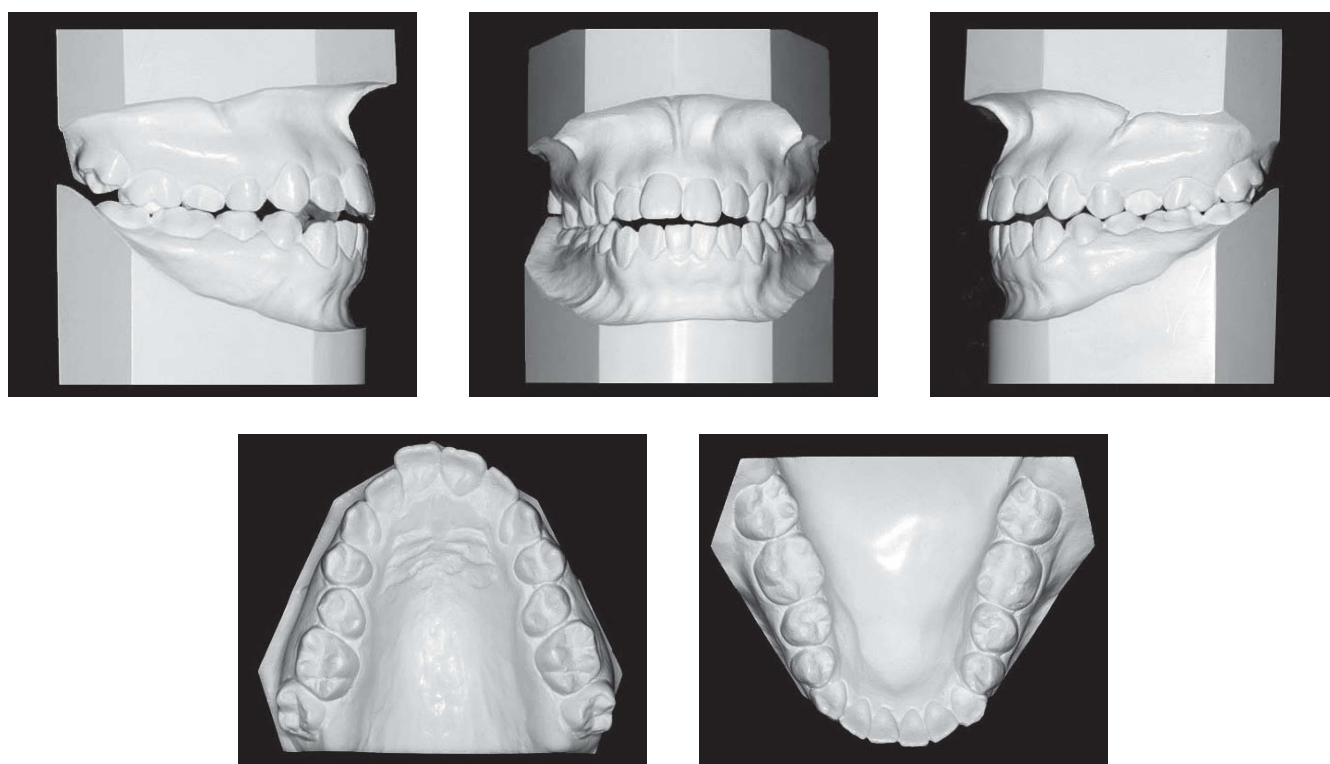


Figure 2 - Initial casts.



Figure 3 - Initial panoramic radiographs.

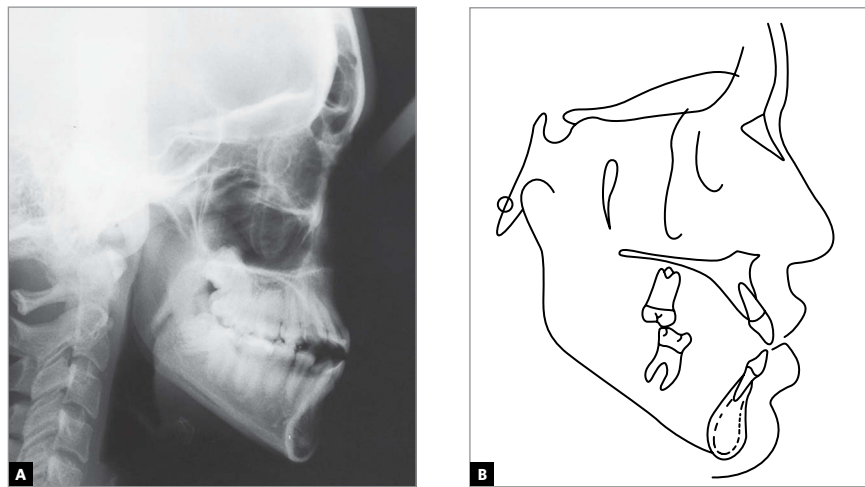


Figure 4 - (A) Initial lateral cephalometric radiograph and **(B)** cephalometric tracing.

expected with direct repercussion on the smile, however, without great alterations in the relationship of skeletal asymmetry between the mandible and maxilla.

TREATMENT PLAN

Two treatment plans were prepared. The first consisted of combined orthodontic-surgical treatment. The patient and his guardians expressed strong rejection of the surgical alternative and asked for another possibility. The other option would be an orthodontic camouflage, with extraction of four permanent teeth and the use of extra-oral appliances. In view of this, the guardians opted for the attempt to perform compensatory treatment and completely discarded the surgical approach.

In the beginning, slow expansion of the maxillary arch with the Hyrax expander appliance was planned. After this, a fixed total appliance with the standard Edgewise system would be placed, requiring extraction of teeth 15, 25, 34 and 44. After the initial stage of alignment and leveling, with the 0.018 x 0.025-in stainless steel rectangular arches already in place, a J-hook extra-oral appliance would be adapted to the mandibular arch, with high pull direction. This appliance would be anchored directly on the arch, touching the canines, functioning as jigs, with the objective of distalizing the mandibular canines and, simultaneously, due to the high pull, promote efficient vertical control favoring rotation of the mandibular occlusal plane in the counterclockwise direction, which would be favorable to the closure of the open bite. Due to the asymmetry and greater need for movement of tooth 43 in the distal

direction, after distalization of tooth 33, the J-hook would be anchored to a hook welded on the arch between teeth 32 and 33, while the right side would continue to play the role of a jig in moving tooth 43.

Meanwhile, in the maxillary arch, closure of spaces would be conducted in a reciprocal manner, with the object of enabling the loss of posterior anchorage in conjunction with retraction and disinclination of the incisors and consequent closure of the open bite.

After this, 0.019 x 0.026-in stainless steel maxillary and mandibular arches would be made, with individualized bends and torques as required and, if indicated, the use of intermaxillary elastics for finishing. Retention in the maxillary and mandibular arches would be performed with wraparound removable retainers.

PROGRESS OF TREATMENT

In the maxillary arch, a modified Hyrax expander appliance was used with bands on the first molars and an extension bonded to the first premolars. After this, Edgewise standard metal brackets, slot 0.022 x 0.028-in, were bonded without torques or angulations. In the mandibular arch, in addition to the fixed appliance, the J-hook extraoral appliance with high pull was used.

Expansion occurred by means of activation by 1/4 turns on alternate days for a period of 30 days. After the active period, the screw was stabilized and the appliance kept in place for three months. After removal of the Hyrax appliance, extraction of teeth 15 and 25 was required and alignment and leveling was performed with a sequence of 0.014-in, 0.016-in, 0.018-in and

0.020-in stainless steel arches. In the mandibular arch, extraction of teeth 34 and 44 was initially required and alignment and leveling was started with a sequence of 0.014-in, 0.016-in, 0.018-in and 0.020-in stainless steel arches. When 0.018 x 0.025-in rectangular archwires were placed, the J-hook was adapted to the mandibular arch with high pull direction (150 g/side). The patient was instructed to use it for a minimum period of 12 hours/day. This appliance was anchored directly on the arch, touching the canines, working as jigs with the purpose of distalizing the mandibular canines and simultaneously to favor rotation of the mandibular

occlusal plane in the counterclockwise direction, which would be favorable to closing the open bite. Due to the asymmetry and the need for greater distalization of tooth 33, after distalization of tooth 33, the J-hook was anchored to a hook welded to the arch between teeth 32 and 33, while the right side continued to play the role of a jig distalizing tooth 43.

Concomitantly, in the maxillary arch, closure of the spaces was performed in a reciprocal manner, with the objective of obtaining posterior anchorage loss together with retraction and uprighting of the incisors, and consequent open bite closure. After this 0.019 x 0.026-in



Figure 5 - Final facial and intraoral photographs.

stainless steel mandibular and maxillary arches with individualized bends and torques were made, as required for finishing. Retention in the maxillary and mandibular arches was performed with wraparound type removable retainers.

TREATMENT EVALUATION

The main treatment objectives were attained, establishing an adequate dental relationship with important repercussion on general facial esthetics and in a more specific manner, significant improvement in the esthetics of the smile, with absence of exposure

of the mandibular teeth (Fig 5), helping to camouflage mandibular asymmetry. It is worth pointing out that a preponderant factor for this successful treatment was the patient's cooperation with the use of extraoral mechanics. With the dental alterations, there was significant change in ANB angle from -2° to 3° (Figs 8, 9 and Tab. 1). This fact can be attributed to remodeling of the alveolar processes in the maxillary and mandibular anterior regions in response to the retraction mechanics used. There was also significant improvement in the inclination of the mandibular and maxillary incisors, with reduction in $\underline{1}$ -NA angle from 34° to 18°

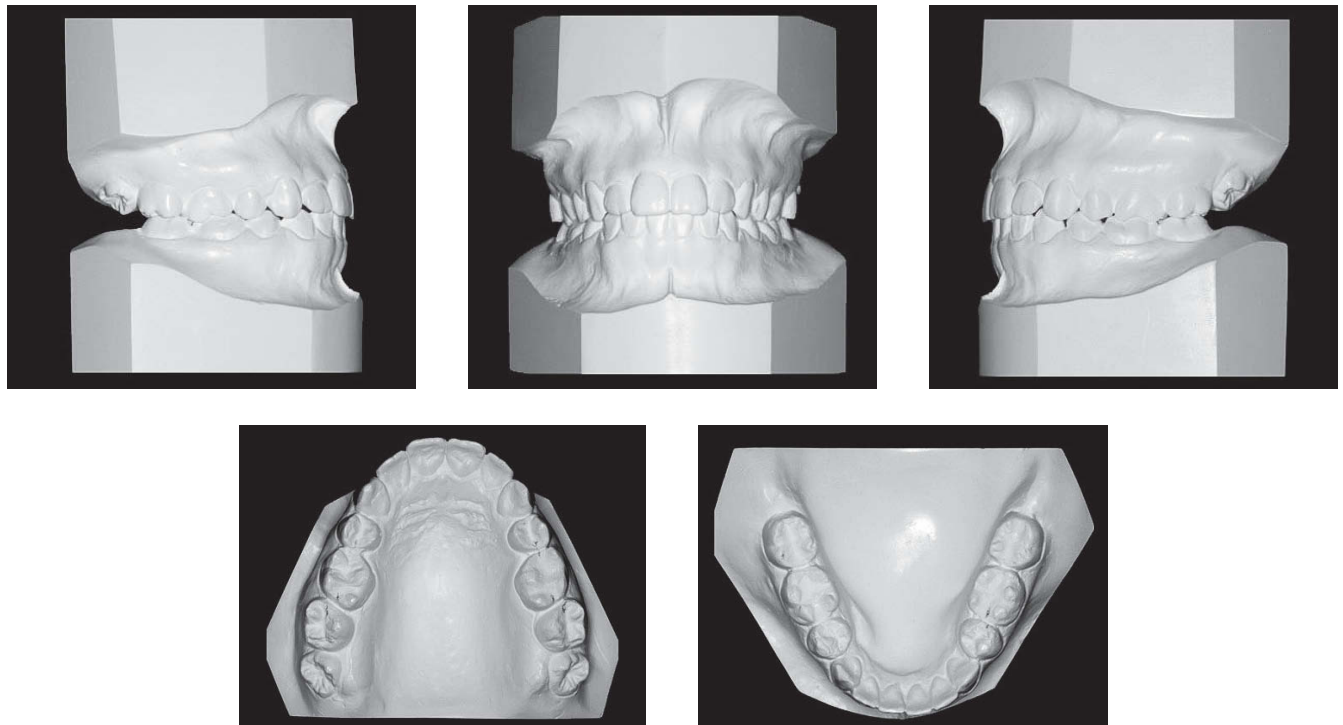


Figure 6 - Final casts.



Figure 7 - Final facial and intraoral photographs.

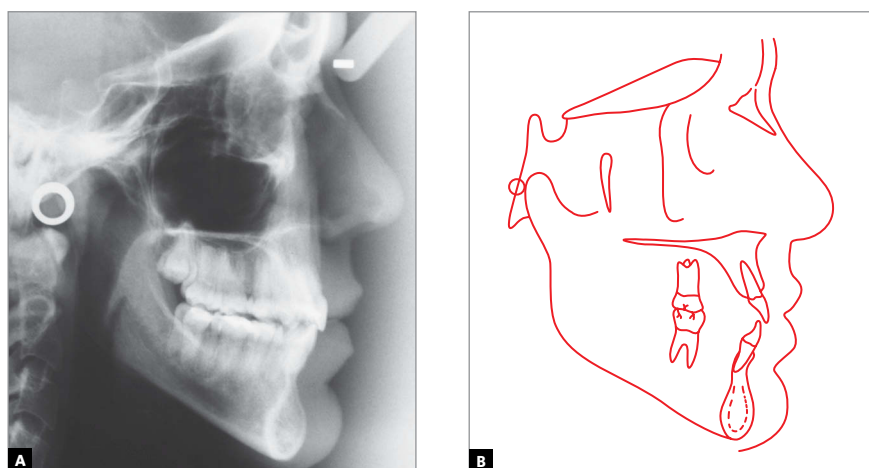


Figure 8 - A) Final lateral cephalometric radiograph and **B)** cephalometric tracing.

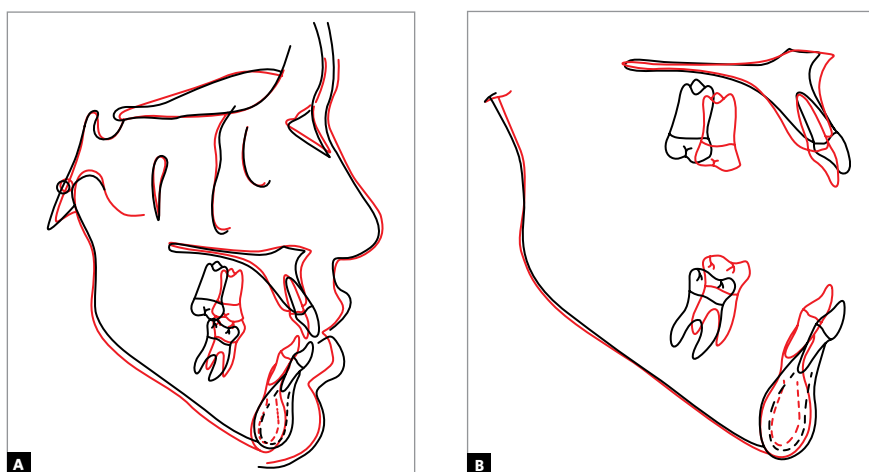


Figure 9 - A) Complete superimposition of the initial (black) and final (red) cephalometric tracings. **B)** Partial superimpositions: Maxilla and mandible.

Table 1 - Summary of cephalometric measurements.

	Measures		Normal	A	B	A/B Difference
Skeletal pattern	SNA	(Steiner)	82°	78°	79°	1
	SNB	(Steiner)	80°	80°	76°	4
	ANB	(Steiner)	2°	-2°	3°	5
	Convexity angle	(Downs)	0°	-3°	2°	5
	Y axis angle Y	(Downs)	59°	66°	69°	3
	Facial angle	(Downs)	87°	82°	80°	2
	Sn-GoGn	(Steiner)	32°	39°	40°	1
	FMA	(Tweed)	25°	37°	40°	3
Dental pattern	IMPA	(Tweed)	90°	93°	86°	7
	1-NA (degrees)	(Steiner)	22°	30°	20°	10
	1-NA (mm)	(Steiner)	4 mm	9 mm	5 mm	4
	1-NB (degrees)	(Steiner)	25°	32°	24°	8
	1-NB (mm)	(Steiner)	4 mm	7 mm	6 mm	1
	1/1 - Interincisal angle	(Downs)	130°	116°	137°	21
	1-APo (mm)	(Ricketts)	1 mm	7 mm	2 mm	5
Profile	Upper lip - S line	(Steiner)	0 mm	1 mm	-1 mm	2
	Lower lip - S line	(Steiner)	0 mm	3 mm	-0,5 mm	3,5

and of I-NB angle from 32° to 24° , with direct repercussion on the closure of open bite and improvement in facial profile (Fig 9 and Table 1). Correct occlusal relationships were obtained for canines and molars and the anterior open bite was corrected. Alignment, leveling and correction of rotations and inclinations were successfully achieved (Figs 5, 6).

FINAL CONSIDERATIONS

The presence of Angle Class III malocclusion, associated with the skeletal discrepancy is a delicate problem in the sphere of Orthodontics.¹ Depending on the magnitude of this discrepancy and the degree of problem of facial esthetics, this problem could have negative psychological repercussions on the social life of an individual, in addition to the functional implications directly related to the stomatognathic system.^{3,4,5}

There are a series of therapeutic resources in Orthodontics for the treatment of Class III malocclusion, which range from interception, for individuals at a early age, all the way to orthodontic-surgical treatment in adults. As an alternative, compensatory orthodontic treatment, also known as orthodontic camouflage, may be applied in certain cases. The main objective of this is to favor satisfactory occlusion by means of dental compensations, however with hardly significant changes in facial esthetics.

In the case described, the patient aging 20 years presented important facial asymmetry and in spite of being informed about the benefit of combined orthodontic-surgical treatment, she and her parents opted for orthodontic camouflage, although they were aware of the limitations of this procedure alone. The nonexistence of family history of similar discrepancy, as well as the report of the patient of being completely prepared to use the orthodontic mechanics provided by the extraoral appliances, were determinant factors in making the decision regarding therapy.

The treatment was performed with tooth extractions, expansion of the maxillary arch and extraoral mechanics acting directly on the mandibular arch, with the purpose of moving the mandibular teeth in the distal direction, correcting the Class III malocclusion and establishing adequate intercuspitation, without side effects on the maxillary arch, thereby applying a modification of the technique described by Tweed-Merrifield.² With expansion of the maxillary arch and reciprocal space closure mechanics, after the extraction of teeth 15 and 25, it was possible to establish correct occlusal relationship for the first molars and canines, as well as adequate levels of overbite and overjet. With the correction of anterior open bite, there was significant improvement in the esthetic of the smile (Fig 5).

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Preparation and evaluation of orthodontic setup

Telma Martins de Araújo¹, Lílían Martins Fonseca², Luciana Duarte Caldas², Roberto Amarante Costa-Pinto³

Introduction: An orthodontic or diagnostic setup consists in cutting and realigning the teeth in plaster models, making it an important resource in orthodontic treatment planning.

Objective: The aim of this article is to provide a detailed description of a technique to build an orthodontic setup model and a method to evaluate it.

Conclusions: Although laborious, orthodontic setup procedure and analysis can provide important information such as the need for dental extractions, interproximal stripping, anchorage system, among others.

Keywords: Orthodontics. Diagnosis and planning. Dental casts.

INTRODUCTION

Plaster casts of the dental arches play a key role in orthodontic diagnosis¹ since, besides revealing the occlusal conditions of the patient in the three dimensions of space, they allow for the performance of many different analysis that assist in orthodontic treatment planning. These include analysis of space discrepancy in mixed and permanent dentition, dental arch symmetry, Bolton discrepancy and orthodontic setup procedure.²⁻⁶

In 1953, Kesling, after developing a tooth positioner as an aid in finishing orthodontic treatments, suggested that cutting and repositioning the teeth in duplicate study models of the malocclusions

would allow simulation of the results before starting orthodontic treatment.⁷

Orthodontic setup is a laboratory procedure that involves cutting and mounting the teeth in dental arch casts, where a drawn up treatment plan based on the diagnosis is tested and changed until the best possible results have been achieved. While it can be quite laborious, it features considerable advantages, especially in borderline cases where there are clinical issues. Using a setup, treatment plans become less speculative, resembling a real treatment and providing orthodontists with reliable information. Research comparing the orthodontic setups of 30 patients using models obtained after treatment

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completion show that setups are a reliable diagnostic resource which can be used as an aid in planning orthodontic treatment.⁷

This article provides a detailed description of the setup procedure as well as a method for evaluating the setup, which allows professionals to extract important information to implement a proposed treatment.

ORTHODONTIC SETUP PROCEDURE

Models must be properly fabricated to faithfully reproduce the patient's malocclusion, then duplicated and polished to streamline the setup procedure. Furthermore, a treatment plan should be selected

for evaluating the diagnostic setup. For a technical description of the orthodontic setup, a 14-year-old dark-skinned patient with Angle Class I malocclusion was used. She had been treated at the Bahia State Federal University (UFBA), at the Specialization Program in Orthodontics at the Édimo Jose Soares Martins Center for Orthodontics and Facial Orthopedics. A treatment plan was proposed after reviewing data collected in the clinical examination, patient history, intra and extraoral images, complementary exams, cephalometric tracing and orthodontic models (Fig 1-3). Facial analysis revealed lip incompetence, convex profile, decreased nasolabial



Figure 1 - Initial facial and intraoral photographs.

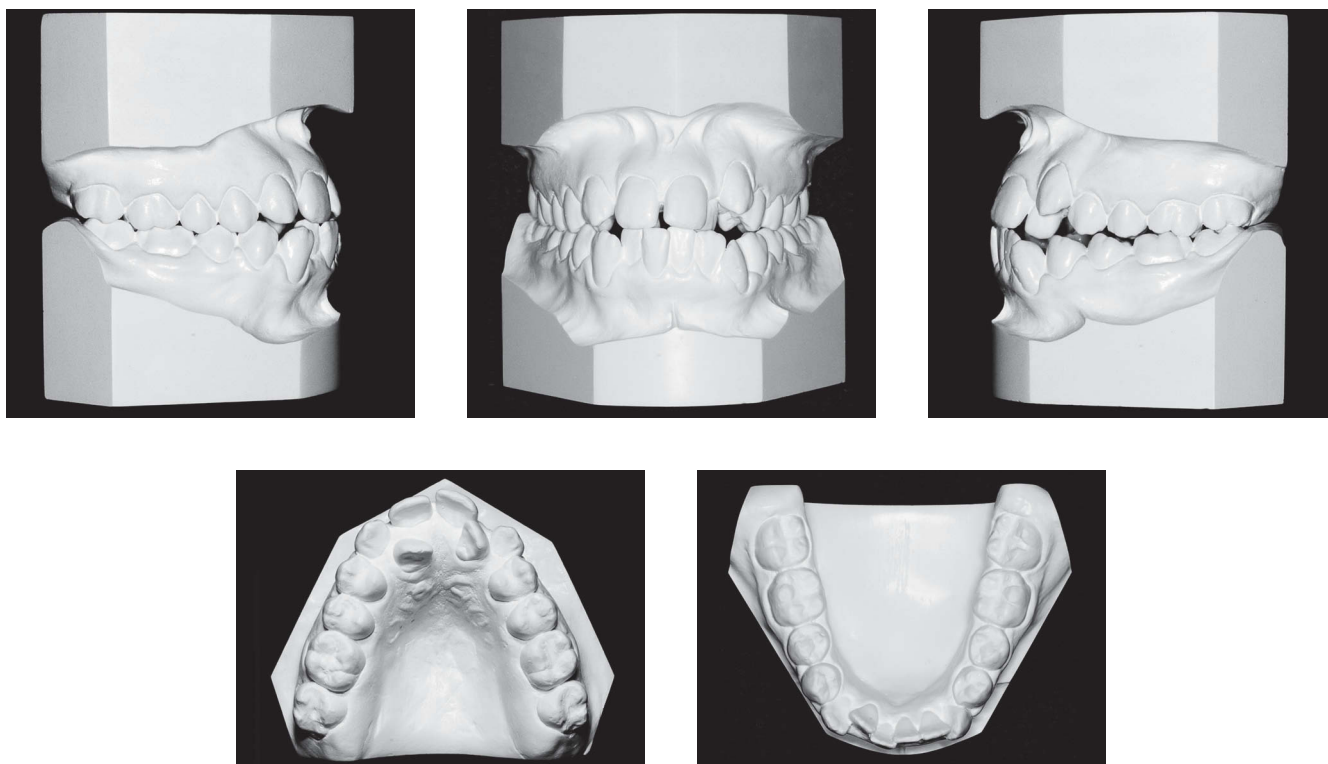


Figure 2 - Initial study models.

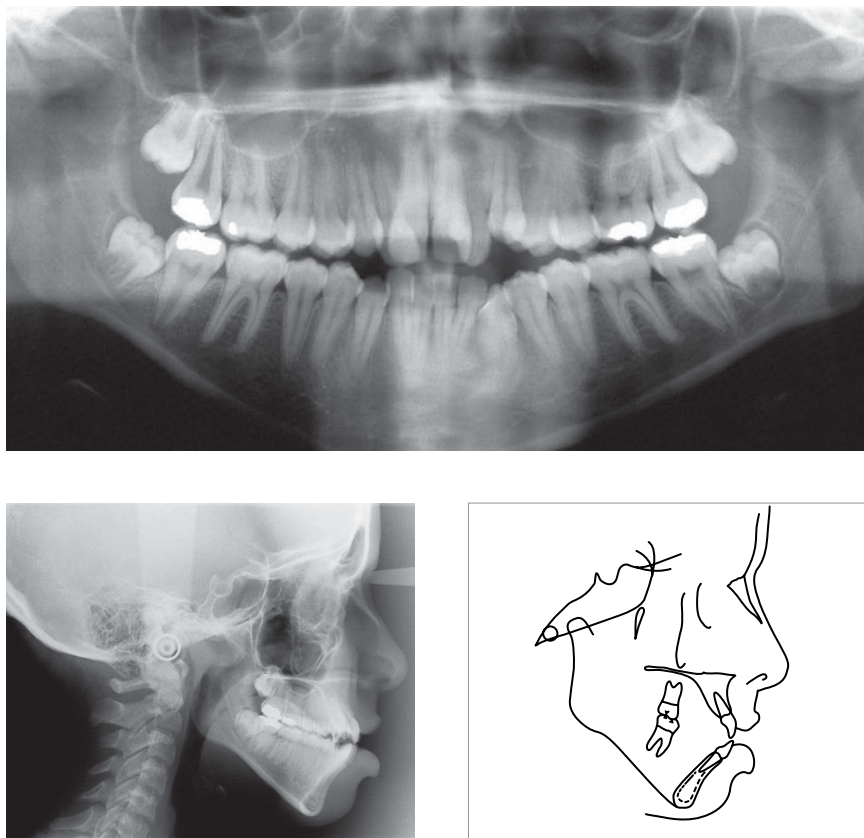


Figure 3 - Initial panoramic X-ray, lateral cephalogram and cephalometric tracing.

angle and malar and paranasal deficiency. She had a Class I skeletal pattern ($ANB=3^\circ$), with a good maxil-lomandibular relationship ($SNA=82^\circ$ and $SNB=79^\circ$) and increased lower facial third ($SN-GoGn=41^\circ$, $AMF=40^\circ$ and $Y-axis=71^\circ$). She had a Class I dental malocclusion, bimaxillary protrusion, upper and lower anterior crowding, with discrepancy of -11.2 mm and -5.5 mm, respectively. Her incisors were in an edge-to-edge relationship, proclined ($1-NA=28^\circ$ and 8 mm, $1-NB=36^\circ$ and 12 mm), and teeth # 12, 22, 24 and 25 in crossbite, in addition to a tooth size discrepancy⁹ showing 2.8 mm excess in the lower anterior region. The degree of complexity found (46 points) made it a highly complex malocclusion.¹⁰

The treatment planned for correcting this mal-occlusion involved the extraction of the upper and lower first premolars to eliminate the discrepancy between the teeth and basal bones, and retracting the anterior teeth to balance the facial profile.

The setup procedure comprises the steps de-scribed next (The list of materials used can be found on the website www.dentalpress.com.br/revistas).

Midline registration

Coinciding the upper and lower dental midlines is one of the treatment objectives, be it for aesthetic and/or functional purposes, be it to accomplish adequate

dental intercuspation in the posterior region of the dental arches. For this reason, the initial position of the midlines deserves utmost attention. To evaluate such position, the patient must be in a standing position during the clinical extraoral examination, with the Frankfort horizontal plane parallel to the ground, and facing the operator. One must then note the position of the upper and lower dental midlines relative to the facial midline. In a front view of the patient at rest and with lips slightly parted, one should imagine a line passing through the groove of the upper lip philtrum, and the distance from this line to a midpoint between the upper and lower central incisors should be estimated. This patient had a greater than 2 mm midline deviation to the right side while the lower midline coincided with the facial midline. The transfer of this in-formation to the bases of the upper and lower plaster models, duly supported on a glass plate, is to be per-formed using 0.5 mm mechanical pencil and a ruler. Thereafter, grooves with depth and width of approxi-mately 1 mm should be made in the demarcated sites using a ruler and stylus (Fig 4).

The grooves corresponding to the initial midlines should be filled with blue wax and heated in a dripper, and the registration of the correct midlines targeted by the orthodontic treatment should be performed using heated #7 red wax (Fig. 5). This information

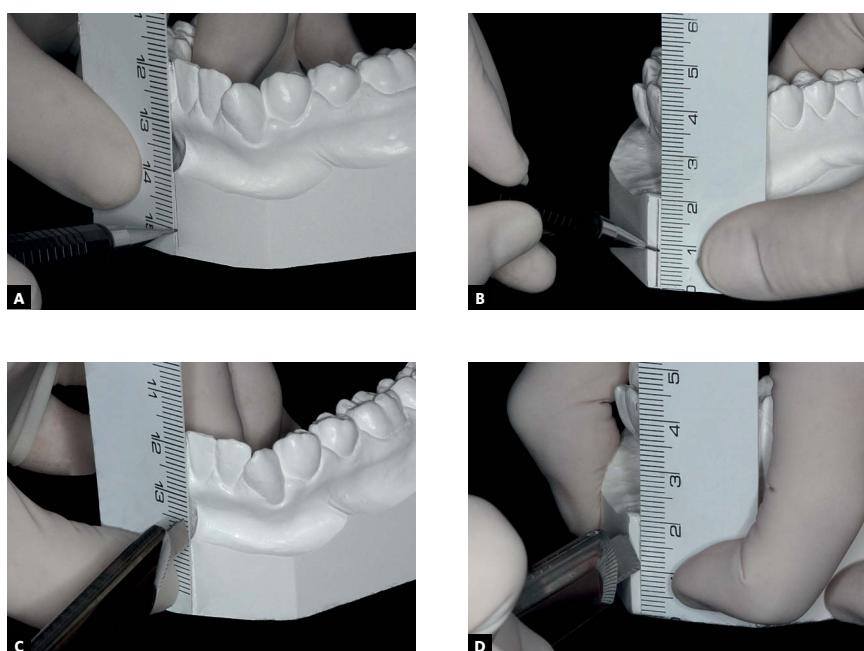


Figure 4 - **A, B)** Record of the initial upper and lower midlines using a ruler and 0.5 mm mechanical pencil; **C, D)** grooves with 1 mm width and depth, made with a stylus.

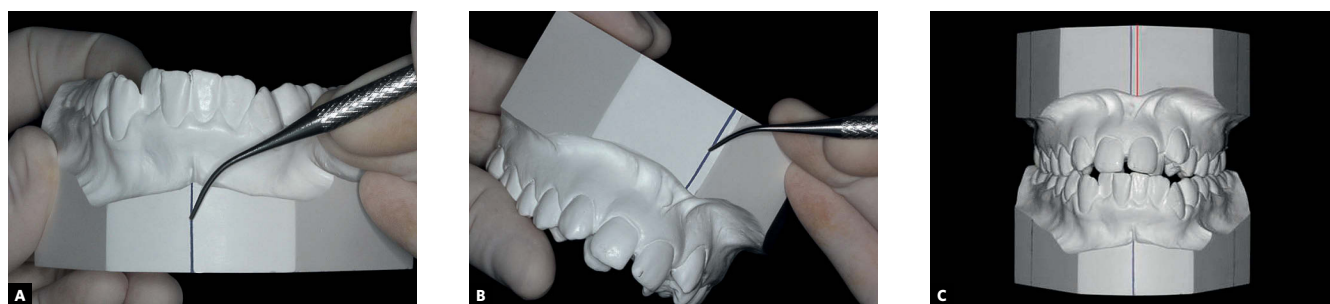


Figure 5 - A, B) Midline grooves filled with heated wax in the lower and upper models; **C)** filled midlines with initial midlines in blue and the changes planned for the upper midline in red.



Figure 6 - A, B) Record of the center of the upper molar mesiobuccal cusp and groove between the mesiobuccal cusp and the median cusp on the lower molar; **C, D)** record of the molar positions on the model bases, and **E)** tooth and base grooves filled with blue wax.



will guide the correct establishment of the midlines when mounting of the teeth.

First molar registration

The mesiodistal axial inclination of upper and lower posterior teeth, preferentially first molars, should also be recorded. In order to verify the axial inclination of these teeth, assuming dental crowns are intact, one can evaluate the relationship between marginal ridges and adjacent teeth, and analyze the relationship of the tooth roots in panoramic and/or periapical radiographs. Once these references have been defined, grooves with width and depth of approximately 0.5 mm should be made on the teeth and model bases. On maxillary molar

teeth the grooves must be marked at the center of the mesiobuccal cusp, and on the lower molars the mark should be made on the groove between the mesiobuccal cusp and the median cusp. Both should be extended to the bases of the models using a ruler. However, should the first molars be missing, the second or third molar may be used as reference. These grooves must be filled with blue wax heated in a dripper (Fig 6). If the first molars are missing, the second or third molars can be used as reference.

Recording the position of the upper and lower molars on the model bases is important to check for changes in the movement of these teeth in the anteroposterior direction, such as loss of anchorage, distalizations or correction of dental inclinations.

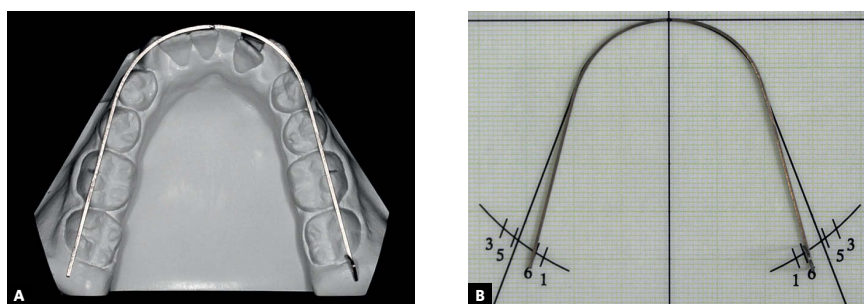


Figure 7 - A) Record of the arch form with 0.021 x 0.026-in stainless steel wire showing its position on the incisal edges and buccal cusps of teeth; **B)** checking the symmetry chart.



Figure 8 - A) Transfer of the midline of the model to the lingual area of the alveolar ridge; **B)** record of the anterior posterior position of the lower incisors using condensation cure silicone; **C)** anterior and posterior incisor extensions of approximately 6 mm.

Lower dental arch form registration

To avoid relapses, studies recommend that the original form of the lower dental arch not be changed to ensure stability of the occlusion achieved with the orthodontic treatment.¹¹ To record the original form, a guiding arch should be prepared using thicker wires, such as stainless steel rectangular 0.021 x 0.026-in or round 0.032-in wires in order to prevent deformation during the phases of the setup procedure. This arch should be fabricated by passing it through the incisal edges of the incisors, canine cusps and buccal cusps of premolars and molars. In mounting the teeth, some modifications may be needed, since the goal is to record the form of the basal bone. Therefore, if the posterior teeth are too buccally inclined relative to the basal bone, the arch should be contracted. If, on the other hand, the teeth exhibit a very pronounced lingual inclination, the arch should have its form further expanded. It is advisable to check the symmetry of this parable in a symmetry chart before starting setup procedure (Fig 7).

Lower incisor registration

The position of the incisors at the end of treatment clearly indicates that a successful, satisfactory occlusion and a balanced profile have been achieved.

First, with the aid of a 0.5 mm mechanical pencil, one should transfer the initial lower dental midline to the lingual area of the alveolar ridge. The registration of the anteroposterior position of the incisors can be carried out with condensation or addition cure silicone. Thus, the model should be placed on a glass plate and receive the silicone, which must encompass the entire anterior vertical portion of the model base, the bottom of the vestibule and buccal and lingual surfaces of the central incisors. To facilitate planning the movement of these teeth, the silicone must be spread about 6 mm anteriorly and posteriorly, starting from the buccal surface of the incisors (Fig 8). After the silicone has set, the registration of the midline marked in the model, in the lingual region of the alveolar ridge, should be transferred to the silicone. This line will serve as a reference to the median cutting of this guide (Fig 9).



Figure 9 - Transfer of the midline marked on the model for the silicone and median cutting of this guide.

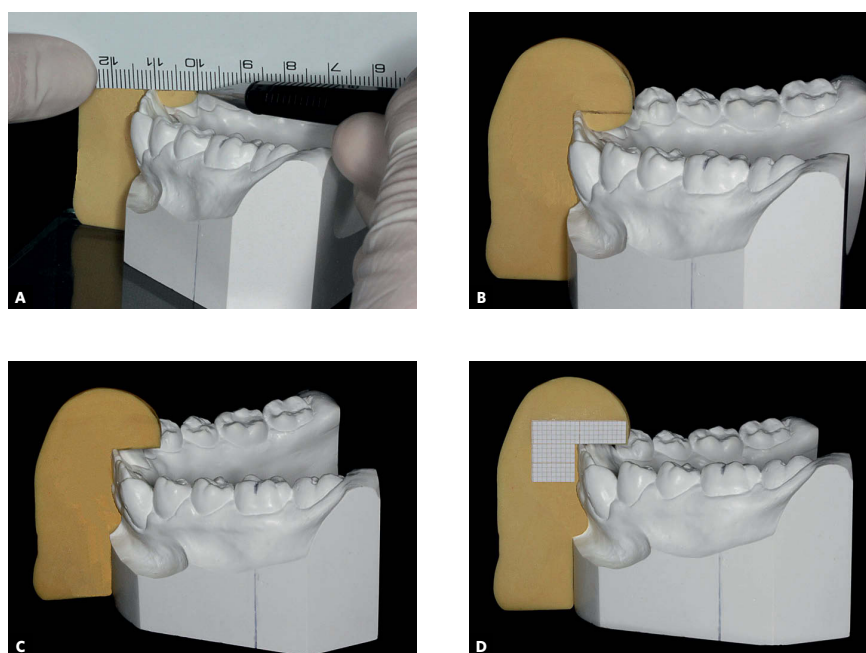


Figure 10 - **A, B, C**) Demarcation and removal of the silicone part in the lingual region of incisors to allow the simulation of the retraction of these teeth; **D**) placement of graph paper.

Then, a piece of graph paper extending vertically and horizontally should be glued to the silicone (Fig 10). This graph paper will serve to quantify the extent to which the simulation of tooth movement is in accordance with the treatment plan, regardless of whether such movement is an intrusion, extrusion, proclination or retroclination. When the treatment plan provides for proclination or extrusion of anterior teeth, before placing the graph paper one should remove part of the silicone in the anterior or superior region to the labial incisal edge, respectively.

Another silicone cure registration must be performed in the posterior region to ensure that the

vertical dimension is accurate between the upper and lower models (Fig 11). This record is particularly important in cases where there is occlusal instability, as in the presence of open bite or when many posterior teeth are missing. Thus, after removal of the teeth and while realigning them, one avoids the risk of deviations in the transverse direction and loss of vertical dimension.

Tooth identification and cutting

Before their removal from the base of the models, the teeth should be numerically identified with pencil 0.5 mm on the lingual surface, to prevent them from being confused when mounting the setup (Fig 12).

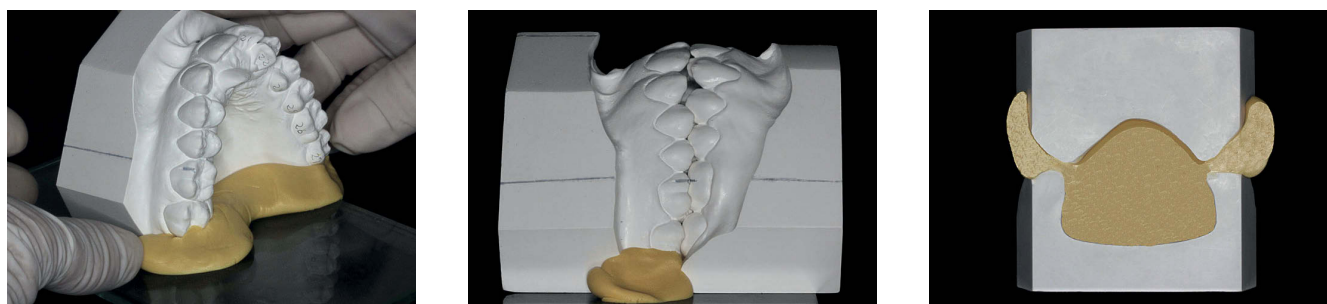


Figure 11 - Registration with silicone in the posterior region to maintain the vertical dimension of the models when mounting the setup model.

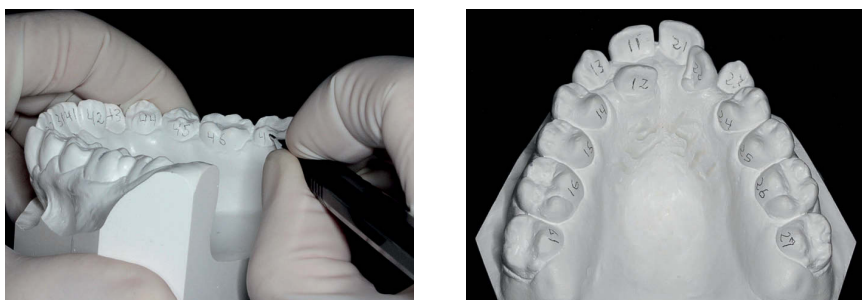


Figure 12 - Tooth identification using 0.5 mm mechanical pencil.



Figure 13 - Demarcation of a guideline for cutting the teeth in the model base in both dental arches.

For the removal of the upper and lower teeth, a line must be drawn limiting the region of the alveolar ridge, approximately 5 mm from the cervical region of the teeth (Fig 13). Some exceptions should be considered, such as buccal ectopia and gingival recession. It is essential to ensure that the tooth stumps that result from cutting the teeth are high enough to be subsequently attached to the wax.

The models must be drilled in the buccolingual direction, with the aid of a #6 round bur mounted in a handpiece, on the limited horizontal line near the midlines of the teeth. The hole diameter should be about 2 mm, sufficient for inserting a thin spiral saw (Fig 14).

The decision regarding from which lower model quadrant one should start cutting depends on several factors, including: Midline deviation, crowding, diastemas, lateral open bites and tooth agenesis. In other words, the block of teeth to be initially highlighted should be opposite to the midline, for example. In this case, the lower dental midline was correct, but had more than 2 mm deviation to the right. Cutting was therefore started on the opposite side, so that the upper incisor on the left was properly mounted in the middle of dental arch, thus leading to the positioning of other teeth in this segment.

After choosing the quadrant, the spiral saw must be inserted into the hole at the base of the model

and attached to a bow saw to enable horizontal cutting as far as the penultimate tooth, but only in the quadrant chosen. It is recommended that the second molars not be initially removed in order to help maintain vertical dimension. From the section in the horizontal direction, new sections between the teeth must be made in the vertical direction using a straight saw, taking care not to break the contact points in order to avoid fracturing the dental structures and compromising the mesiodistal dimension of the teeth (Fig 15). After the horizontal and

vertical cutting, an explorer #5 must heighten the interdental limits, providing a guide for the fracture line. Only then should a light finger pressure be applied to weaken the embrasures and separate the teeth (Fig 16). The plaster stump of each tooth should be stripped with a steel or tungsten dental bur, slenderizing the stump while carefully preserving the mesiodistal dimension of each tooth without removing the dentogingival limit (Fig 17).

Once the teeth have been prepared, their mesiodistal dimensions should be checked with a caliper,



Figure 14 - Drilling in the area of the lower alveolar ridge on the horizontal line near the midline for insertion of the thin spiral saw.

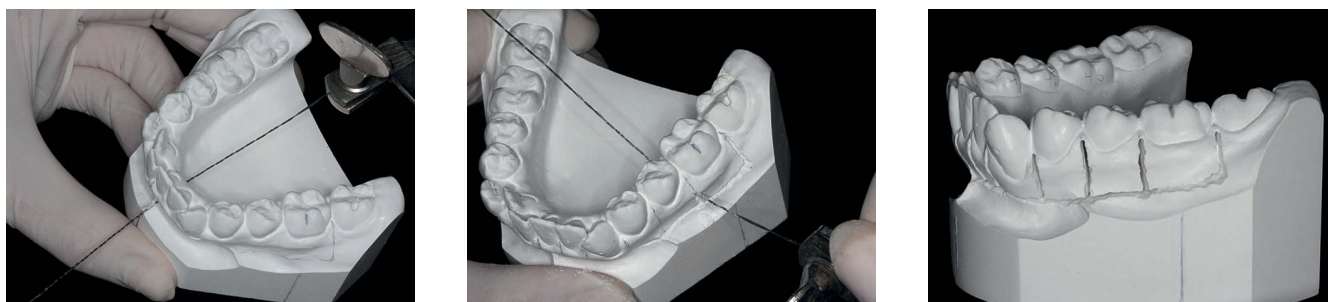


Figure 15 - Horizontal and vertical sections in the lower alveolar ridge of the left quadrant using thin spiral saw mounted on the frame of a bow saw.

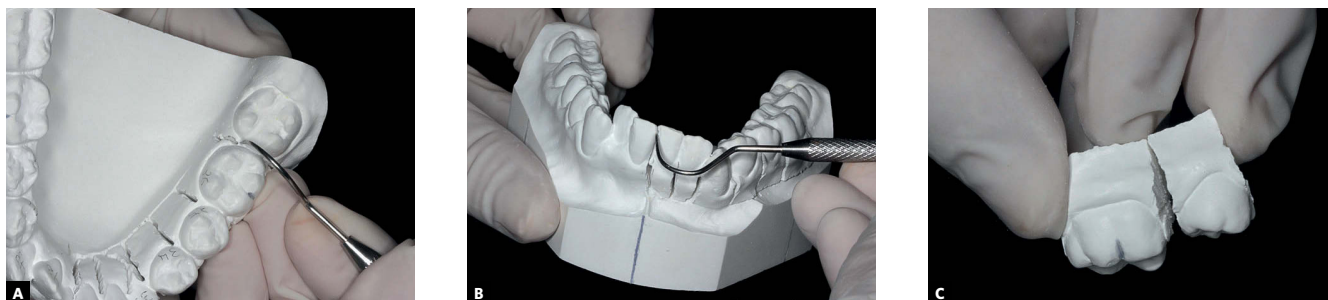


Figure 16 - **A, B**) Explorer #5 being used to heighten the interdental limits; **C**) after separating the block of teeth from the model; some finger pressure should be applied to the stumps to separate teeth.

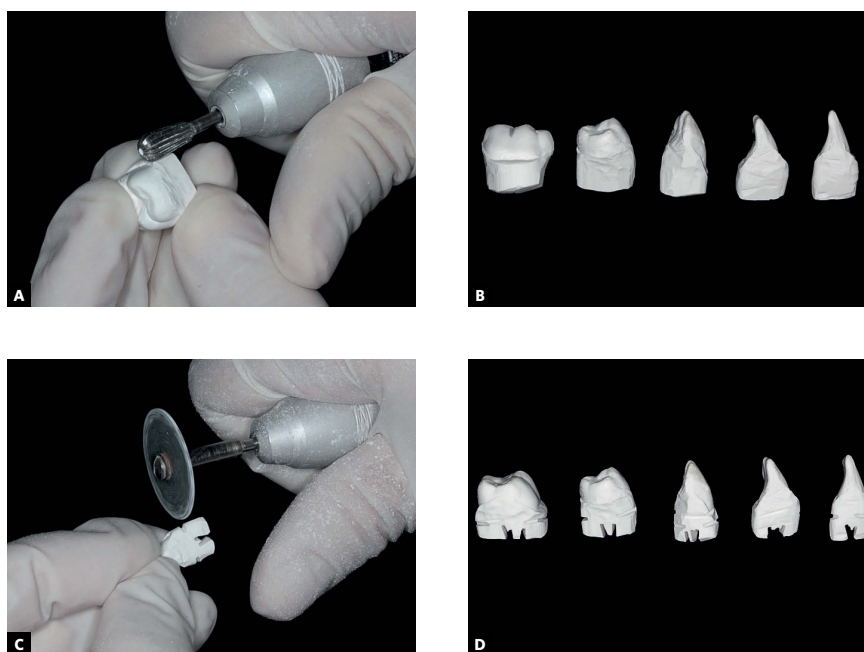


Figure 17 - A, B) Stripping the tooth stumps with a steel bur, taking care to maintain the mesial-distal dimension of each tooth, without removing the dentogingival limit; **C, D)** making retentions in the stumps with a carborundum disk.

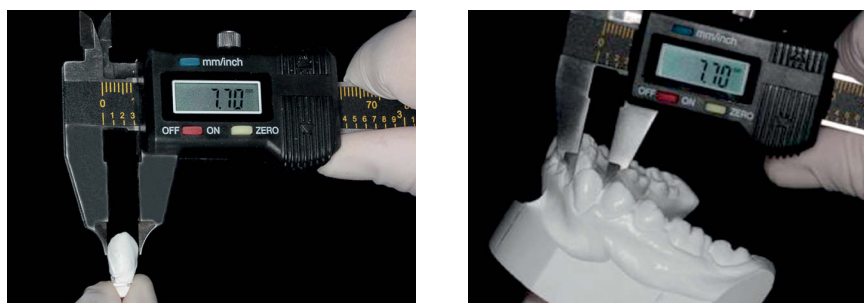


Figure 18 - Use of a digital caliper to check the mesiodistal dimension of each tooth after cutting, comparing it with the original value in the initial study model.

comparing them with the sizes of the original model of the initial study, which recorded the patient's malocclusion (Fig 18).

Following, the area corresponding to the base of the alveolar model should be leveled flush with a steel or tungsten carbide cutter to avoid interferences when mounting the teeth. A central groove should be made in the ridge area using the same cutter to preserve the buccal and lingual boundaries of the region, as these will be useful when carving the wax. Subsequently, small cavities should be bored with a round bur #6 in order to create retention for insertion and fixation of the wax. Soon

afterwards, any debris that may interfere with the wax adhesion should be removed with a brush and/or compressed air (Fig 19). This entire sequence of procedures should be performed in the ipsilateral quadrant in the upper arch.

Tooth mounting

To mount the teeth, the model base should be prepared in the following sequence: Complete filling of the central groove in the alveolar base with a layer of melted red wax #7; placing of a strip of utility wax, also red, with a height of approximately 6 mm (Fig. 20). Using a silicone bite registration, the lower central

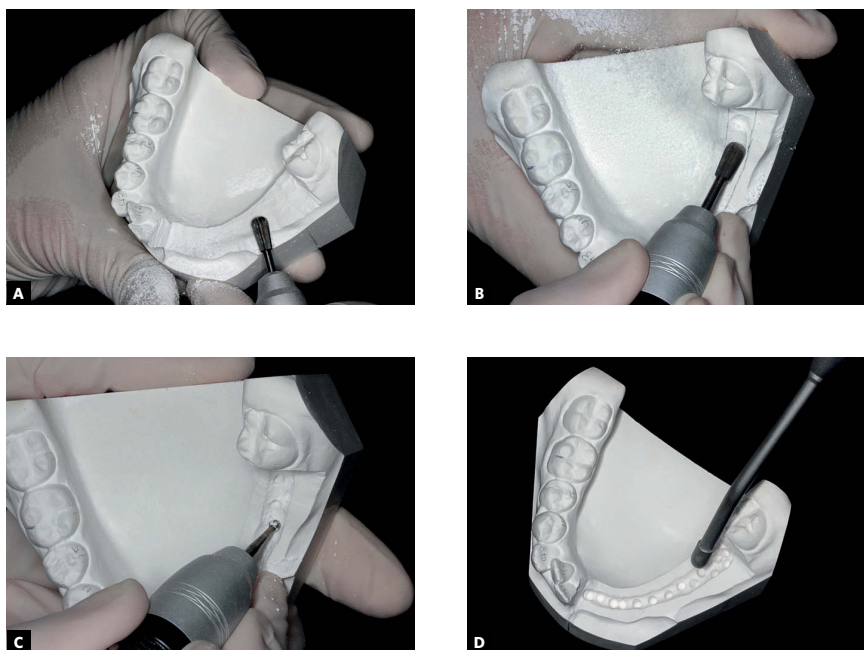


Figure 19 - **A, B)** Leveling the lower alveolar base and making a central groove; **C)** boring small holes (cavities) with a round bur #6 to create undercuts; **D)** removal of plaster residues using a compressed air syringe.

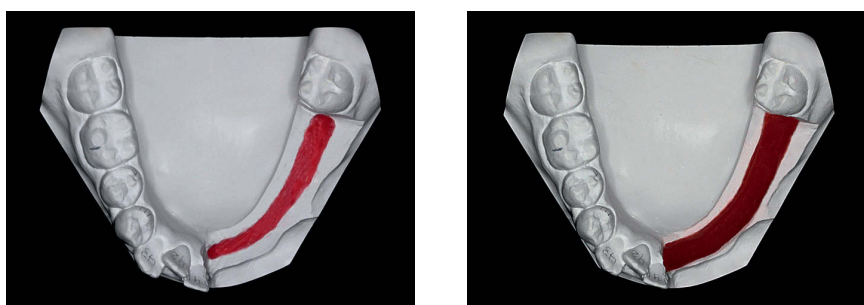


Figure 20 - Filling the central groove of the alveolar ridge with red wax #7; a strip of utility wax is attached to the red wax to allow the teeth to be set in place.

incisor is positioned in the utility wax according to the changes proposed in the treatment plan, considering proclination, retraction, intrusion or extrusion. Next, the remaining teeth are positioned using as reference the archwire form which best represents the original dental arch form (Fig 21). A 3 mm retraction was planned in this case for the lower incisors. After determining the position of the teeth, excess utility wax is removed and the spaces between the teeth filled with hot wax #7 (Fig 22).

When mounting the teeth one should follow the guidelines and the six keys to a normal occlusion introduced by Robert Strang¹² and Lawrence Andrews,¹³ whereas the arch form and intercanine and intermolar widths should be preserved.

Once one of the lower quadrants has been fully mounted, the same procedures should be repeated in mounting the upper teeth on the same side, ensuring the best possible intercuspation, while maintaining the vertical and transverse dimensions (Fig 23). After mounting is completed on one side, one must repeat all procedures on the other side of the dental arch (Fig 24).

Once the vertical dimension has been preserved through the occlusion of the premolars and molars, the second molars are removed and mounted. One should, however, ascertain that posterior cutting be performed precisely on the distal surface of the second molars, thereby monitoring the amount of movement that occurs in the posterior segment

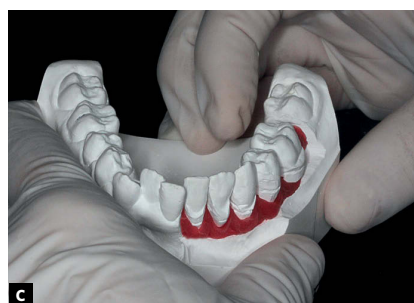
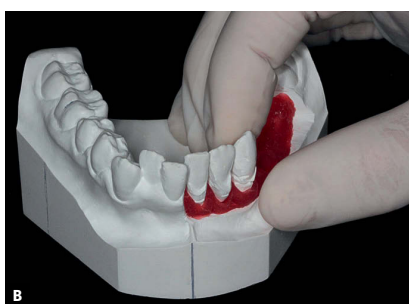
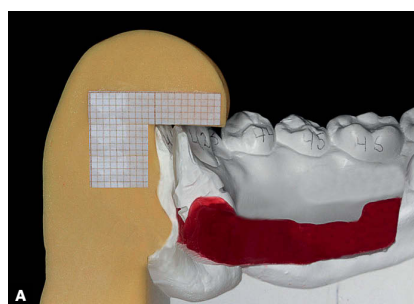


Figure 21 - **A)** Positioning the lower left central incisor in accordance with the proposed reduction of 3 mm in the treatment plan; **B, C)** mounting the remaining quadrant teeth; **D)** checking for the correct tooth positions using the archwire from the arch form registration.

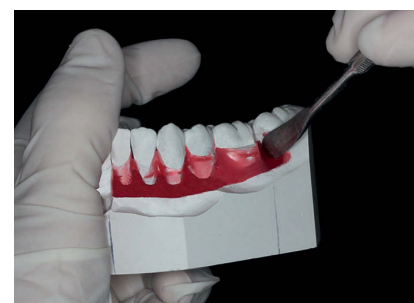


Figure 22 - Setting the tooth stumps with heated red wax #7.

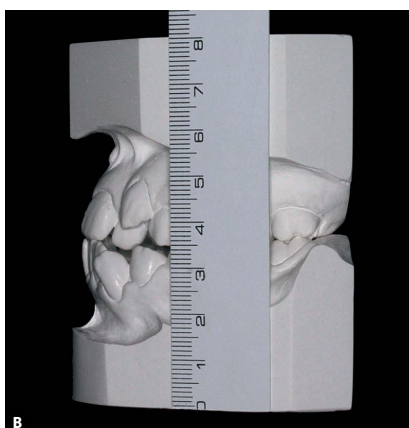
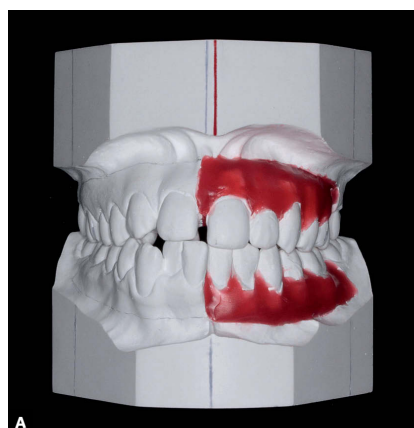


Figure 23 - **A)** Mounting of teeth on the upper and lower left side as far as the first molars; **B, C)** checking to ensure maintenance of the vertical dimension, considering the total height of the bases (initial and setup); if necessary, use of posterior silicone record, illustrated in Figure 11.

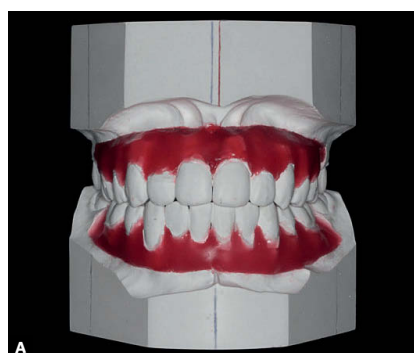


Figure 24 - Mounting the left and right quadrants as far as the first molars. The archwire registering the original archform (Fig 7) should be used to check the shape and symmetry of the lower arch construction.

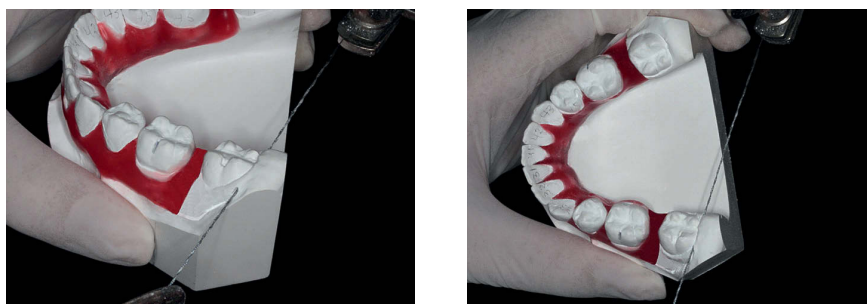


Figure 25 - Careful removal of the lower second molar, ensuring that the posterior cutting is done exactly on the distal surface of the tooth.

of each quadrant (Fig 25). Once mounting is complete, the occlusion should be checked in its contact points, marginal ridge height and axial inclination of the anterior and posterior teeth.

Waxing, carving and finishing

Heated red wax #7 should be placed over and around the stubs, from the alveolar base to the cervical region of all teeth. This type of wax is used because of its greater strength and superior conservation of the setup. The gingival margins are then shaped using a Hollemback carver taking into account the height and shape of the crowns and original zeniths of each tooth. Maintaining the gingival margin while preparing the teeth can assist in the process of

carving and waxing. The wax should be plasticized using a Hannau type lamp, rendering it thoroughly even and smooth. For finishing, the models should undergo a second procedure, namely, pearling. To this end, the setup should be dipped in a container with soap solution, with the teeth facing down, thus allowing all surfaces to submerge. Within no longer than two hours, the models must be removed from the solution, washed in running water, and rubbed with cotton soaked in the same solution. Finally, it should be allowed to dry for at least 24 hours in a ventilated, dust free environment, on absorbent paper, with the teeth facing downwards. Plaster polishing should be accomplished by rubbing a silk fabric on the teeth and model base (Figs 26, 27).

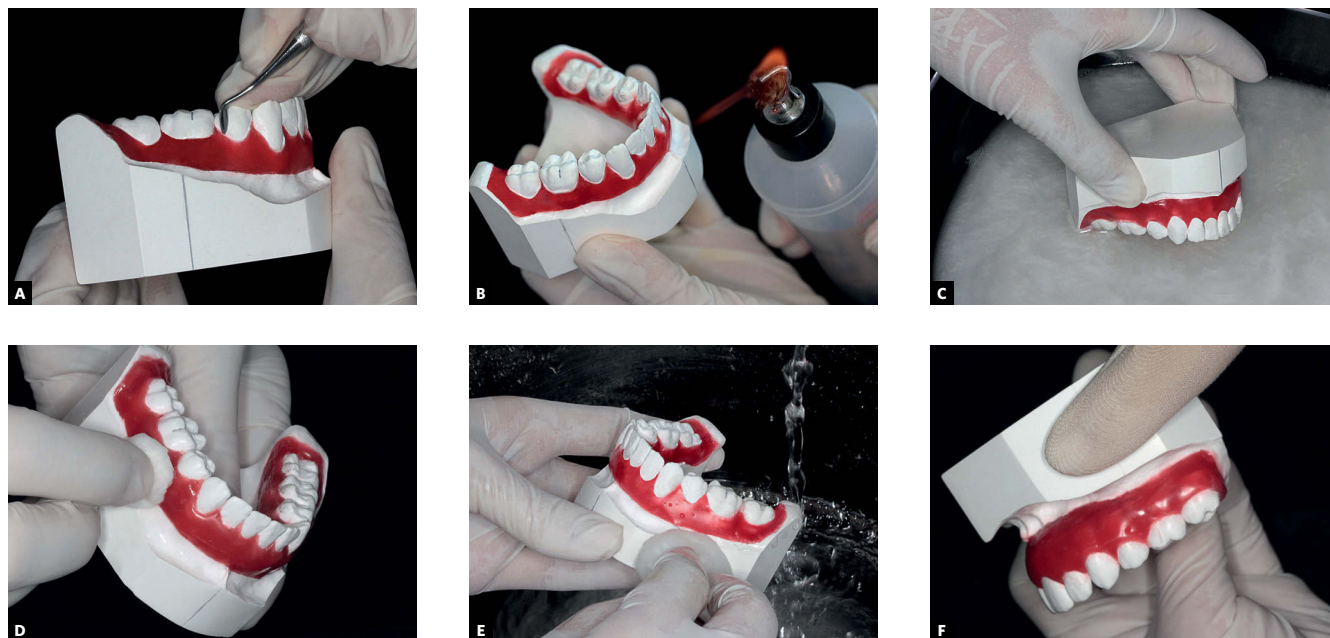


Figure 26 - **A)** Adjustment and shaping of the gingival margins with a Hollemback carver; **B)** wax plasticized with the aid of a Hannau lamp to ensure total smoothness; **C)** immersion in soap solution; **D)** washing in running water to remove residues; **E)** plaster polished with silk fabric; **F)** polishing of gypsum with silk fabric.

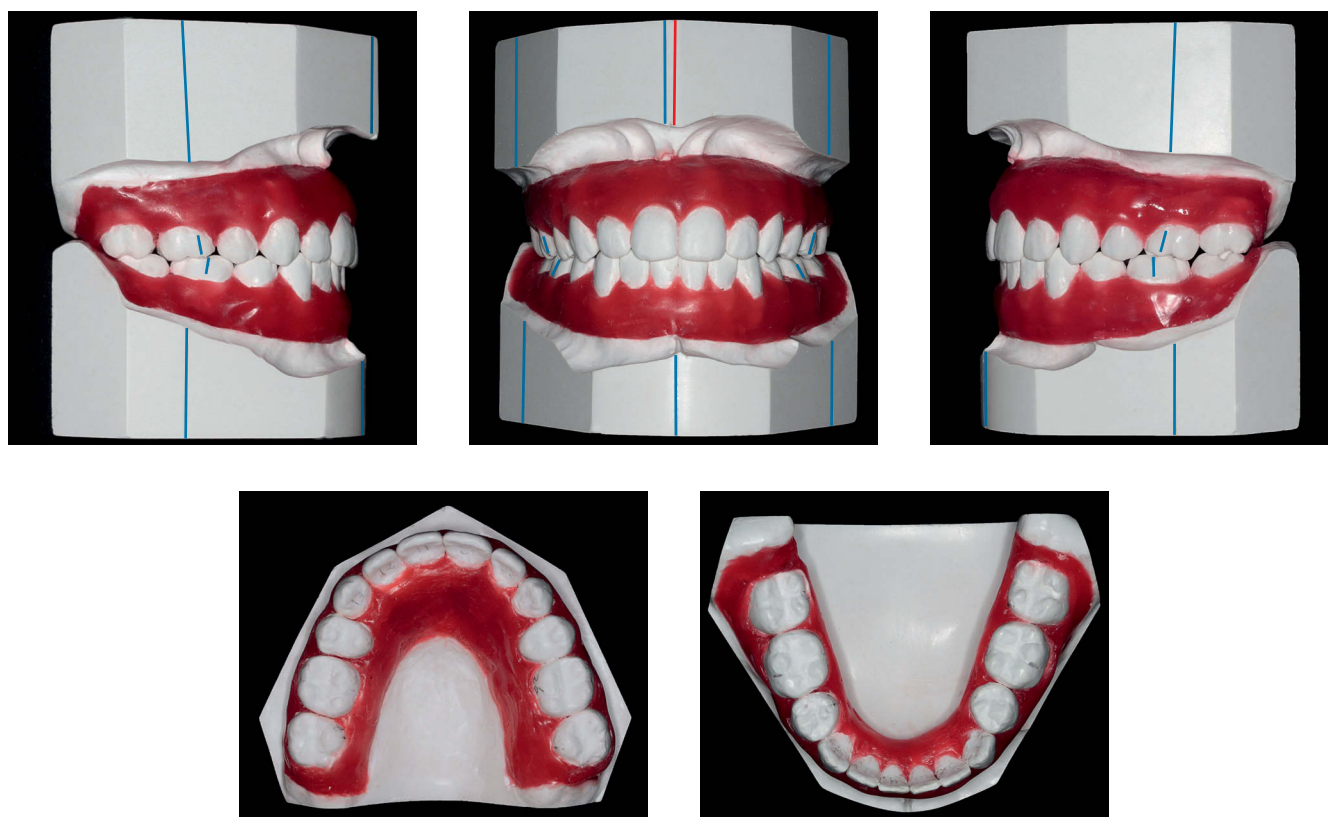


Figure 27 - Finished setup model.

SETUP ANALYSIS

Once the setup is ready, much information is generated and if a judicious method is not used to analyze it one may not derive its full benefits. The use of an evaluation form based on the model, first suggested by Cury-Saramago and Vilella¹⁴ is recommended. The proposed method includes ten items: Extractions, changes in the basal bones, lower incisor position, leveling, midlines, dental arch form, molar and canine relationship, anchorage, interproximal stripping and cosmetic finishing (Fig 28). The manner in which data are acquired and recorded, as well as the type of information that can be obtained will be presented below, along with remarks on the analysis of the clinical case presented in this article (Fig 27).

Extractions

Under this topic one should record the extractions which were necessary for treating the malocclusion. Additionally, the mesiodistal dimensions of the extracted teeth should be recorded as these

dimensions are an indication of the space gained for alignment, leveling, repositioning of the anterior teeth and correction of the midlines. In the example described above, teeth numbers 14, 24, 34 and 44 were extracted, resulting in a space gain of 16.8 mm in the upper and 17 mm in the lower arch.

Basal bones

Under this item one should record the amount of growth planned for the treatment period, and the extent of maxillary/mandibular advancement or setback determined in planning orthognathic surgery, which can be measured by the extent of wax placed on the posterior edge of the models. Since this was not a growing patient and surgery was not planned, nothing was recorded on the card.

Lower incisors

The type and amount of movement performed in mounting these teeth (retraction, proclination, intrusion, extrusion) must be recorded. In this example,

SETUP ANALYSIS

Patient: **ACGB** Age: **14 years** Date: **04/29/2002**

1. EXTRACTIONS

1.1 Yes: (X) **Teeth 14, 24, 34 and 44** No: ()

1.2 Space gained: Upper **16.8 mm (8.4 + 8.4)** Lower: **17 mm (8.5 + 8.5)**

2. BASAL BONES

2.1 Growth: () Surgery: () None: (X)

3. LOWER INCISORS

3.1 Retraction: (X) **3 mm** Proclination: () Maintenance: ()

3.2 Intrusion: () Extrusion: ()

4. LEVELING

4.1 Overbite - Initial: **0 mm** Setup: **2 mm**

4.2 Intrusion: () Extrusion: (X) **upper incisors**

5. MIDLINES

5.1 Upper - Initial: **deviated 2 mm to the right** Setup: **coincident**

5.2 Lower - Initial: **coincident** Setup: **coincident**

5.3 Space - Extraction: (X) **pre-molars** Distalization: () Interproximal stripping: ()

6. DENTAL ARCH FORM

6.1 Lower - Expansion: (X) **canines** Contraction: (X) **molars** Maintenance: ()

Widths - Intermolar - Initial: **45 mm** Setup: **44 mm** Intercanine - Initial: **26.5 mm** Setup: **28 mm**

6.2 Upper - Expansion: (X) Contraction: () Maintenance: ()

Widths - Intermolar - Initial: **51 mm** Setup: **52 mm** Intercanine - Initial: **30.5 mm** Setup: **37 mm**

7. MOLAR AND CANINE ANTEROPOSTERIOR RELATIONSHIP

7.1 Intermolar - Initial: Right: **Class I occlusion** Left: **Class I occlusion**

Setup: Right: **Class I occlusion** Left: **Class I occlusion**

7.2 Intercanine - Initial: Right: **Class I occlusion** Left: **Class I occlusion**

Setup: Right: **Class I occlusion** Left: **Class I occlusion**

7.3 Intercuspation - Satisfactory: (X) - Limitations: ()

8. ANCHORAGE

8.1 Anchorage loss: (X) Upper Right: **3.5 mm** Left: **3.0 mm** Lower Right: **4.0 mm** Left: **3.5 mm**

8.2 Distal movement: () Upper Right: Left: Lower Right: Left:

9. INTERPROXIMAL STRIPPING

9.1 3 to 3 - Upper: () Lower: (X) **2.8 mm in teeth 32, 42, 33 and 43**

9.2 4 to 6 - Upper: () Lower: ()

9.3 Tooth size discrepancy - 6 anterior teeth: (X) **2.8 mm lower teeth** 12: ()

10. COSMETIC FINISHING

10.1 Stripping: (X) **lingual marginal ridges of teeth 11 and 21**

10.2 Augmentation: ()

Figure 28 - Form used for setup analysis.

there was a 3 mm retraction of the lower incisors to decrease dental protrusion (Fig 21A). It is noteworthy that in this case the space for incisor alignment and retraction was gained by extracting the first premolars.

Leveling

To assess changes in dental leveling one should note the amount of overbite and curve of Spee present in the initial malocclusion, and the correction made in the setup. It is important to stress that this leveling occurred by intrusion or extrusion of anterior or posterior teeth accomplished according to the diagnosis and treatment plan. In the case presented in this study, the edge-to-edge relationship in the anterior region identified at the beginning of treatment was corrected by extruding the upper incisors.

Midlines

One should record the changes made in the upper and lower midlines (Fig 27), and how space was obtained for this procedure, such as premolar extractions, distalization of posterior teeth or stripping. In the setup described in this study, the upper midline was corrected by deviating it 2 mm to the left; space was gained from premolar extractions.

Dental arches

In order to evaluate the lower dental arch form once the setup is complete, one should use an arch-wire form compatible with the original dental arch form (Fig 7). In this case, it can be observed that the form was retained to the extent possible (Fig 24C). One should also compare the distances between the upper and lower canines and molars on the setup with the measurements obtained from the models that contain the malocclusion, and record the changes. In the clinical case there was practically no changes in the intermolar distance in both arches, the intercanine width, on the other hand, increased due to the fact that these teeth were distalized to achieve leveling, alignment and incisor retraction.

Molars and canines

In this section, one should record, in addition to the initial relationship of these teeth, the position they occupy after simulating the treatment, and

report whether they are in normal occlusion, Class II or III malocclusion. At this point, one can also observe if major changes were needed in molar inclination. This reading can be performed by extending the registration of the molar positions, performed at the base of the model, as far as the corresponding marks in the aforesaid teeth at their final positions (Fig 27). Intercuspalation should be assessed, and any difficulty in mounting the setup, noted. This step is important as it enhances treatment predictability given the possibility that the same problems may also occur during orthodontic therapy. In this case, the relationship of the molars and canines in the anteroposterior direction was maintained. Intercuspalation was improved thanks to the space obtained from the extractions.

Anchorage

Any anterior posterior movement observed in the molars must be recorded. For this purpose, a ruler is placed on the base of the model, and the registration line is extended from the starting position of the molars. Thus, one can measure with another ruler the amount and direction (mesial or distal) of tooth movement. Another form of assessment is to measure the distance between the distal end of the last tooth and the retromolar region in the upper and lower arches. However, this method is effective only if this region has been carefully cut at the distal end of the last tooth in the setup model. This information will be useful for planning the anchorage to be used in the orthodontic treatment of the malocclusion. In the case described in this article, 3.5 mm anchorage was lost in the upper right quadrant, 3 mm in the upper left quadrant, 4 mm in the lower right quadrant and 3.5 mm in the lower left quadrant. Planning the anchorage for treating the aforementioned malocclusion required the use of a Nance button and lingual bar.

Interproximal stripping

Whenever stripping is required, the mesiodistal dimensions of the teeth involved should be recorded before and after stripping. Thus, one can calculate the amount of interproximal stripping performed on each tooth to obtain proper alignment of dental and/or inter occlusal relationship, be it in the anterior or

posterior segment, or both. It is important to note that this stripping should only be carried out when Bolton discrepancy⁹ is present, or else a Bolton discrepancy will be created in the opposing arch. Prior to stripping, one should also ascertain that the sizes of all teeth are symmetrical, since if tooth symmetry is not present, the teeth with larger mesiodistal dimensions should be stripped first, thereby establishing symmetry with the homologous teeth. In the case

presented as an example, there was tooth size discrepancy with a 2.8 mm excess in the six lower anterior teeth, making it impossible to perform full space closure in the anterior maxillary arch. Stripping was therefore performed on the mesial surface of teeth 33 and 43 and on the mesial and distal surfaces of teeth 32 and 42. This procedure proved important in resolving the Bolton discrepancy and accomplishing a proper inter incisal relationship.



Figure 29 - Finished treatment showing the treatment objectives were achieved according to plan.

Cosmetic finishing

At this point, the details that were necessary for properly finishing the orthodontic treatment should be recorded, such as the stripping of the palatal marginal ridges on upper incisors so as to establish a correct overjet, or bulky or accessory cusps that may interfere with a proper posterior intercuspation. The need for gradual reshaping in the case of microteeth, asymmetries of homologous teeth, Bolton discrepancy, or large teeth showing signs of substantial incisal wear should also be noted. After achieving the best possible intercuspation it is important to record the factors that hindered the achievement of an even better intercuspation. Some such factors are the presence of eccentric or worn cusps, restorations with improper shape or size, as well as teeth with increased or decreased buccolingual dimensions. In this case, some stripping of the palatal ridges of teeth 11 and 21 was performed.

FINAL CONSIDERATIONS

In reviewing the treatment outcome of the patient that illustrates this article, it becomes clear that the planned objectives were achieved: Pleasing face and smile, good occlusal relationship, lip competence, straight profile, the Class I skeletal pattern ($ANB=2^\circ$) was preserved, with a good relationship between maxilla and mandible ($SNA=81^\circ$ and $SNB=79^\circ$), the vertical pattern was maintained ($SN-GoGn=40^\circ$, $FMA=39^\circ$, $Y\text{ Axis}=69^\circ$) and incisor positioning improved ($I-NA=28^\circ$ and 6 mm; $I-NB=22^\circ$ and 5 mm) (Figs 29 – 31). In the cephalometric superimpositions (Fig 32) one can see that incisor retraction and anchorage loss in the upper and lower arches occurred according to how the setup was planned and constructed. After performing an analysis of the manner in which the treatment was finished in dental casts and radiographs, as recommended by the American Board of Orthodontics,¹⁵

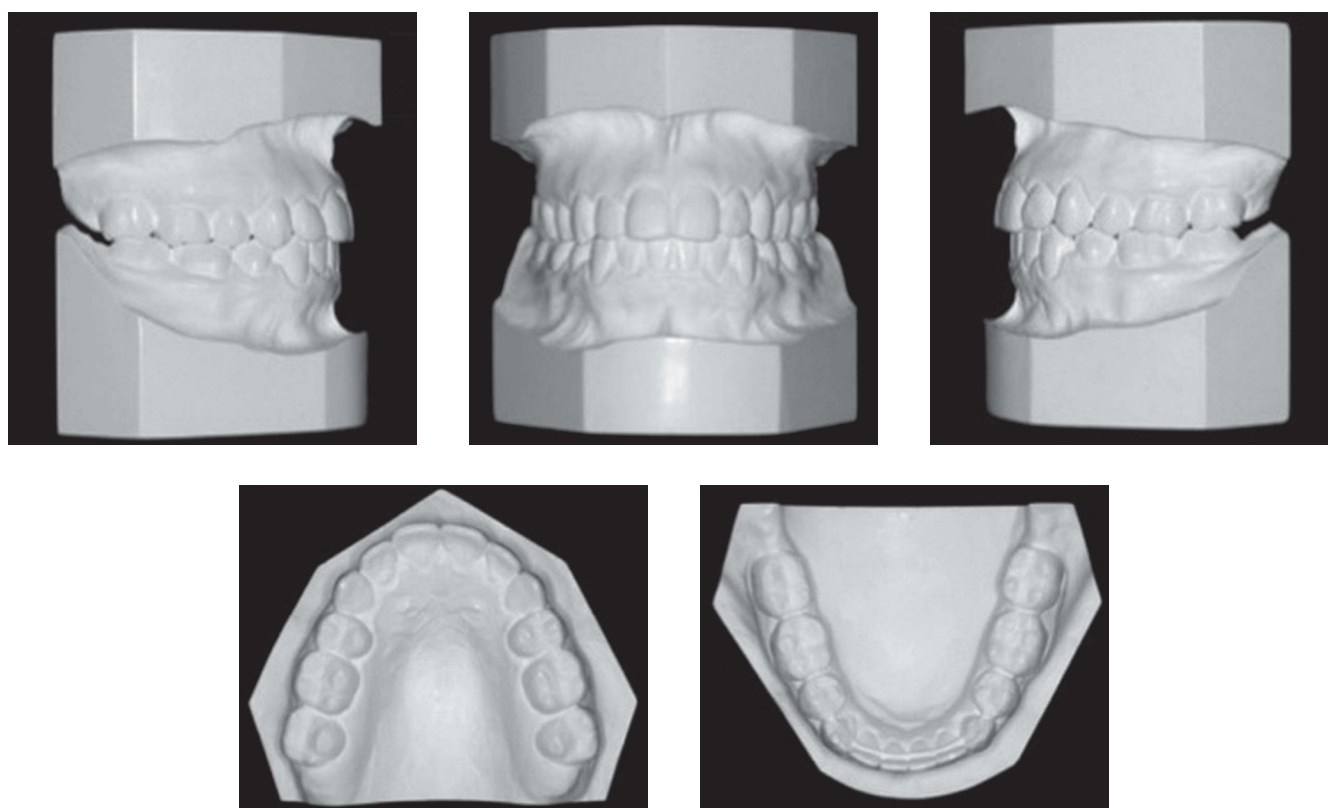


Figure 30 - Final study models.

this treatment received 9 points, which is considered a good finishing score.

With the development of and reduction in the cost of three-dimensional scanning technology, along with the ability to perform computerized analyses, virtual models of the dental arches have become increasingly common in clinical orthodontics. The computer programs designed to meet this market demand are becoming increasingly effective and thorough. Today, it is possible to quickly and easily analyze asymmetries, space discrepancies,

tooth size, among other features. OrthoAnalyzer® software, for example, includes a tool to build digital setups (Fig 32). After scanning the model, treatment simulation is performed similarly to a conventional mounting. The teeth are separated, extractions can be performed and teeth moved in all directions. The mounting must be initiated by repositioning the lower incisors. One side should be mounted at a time and the arch form can be maintained. However, to ensure that the digital setup is reliable the operator should be skilled in the sequence and careful

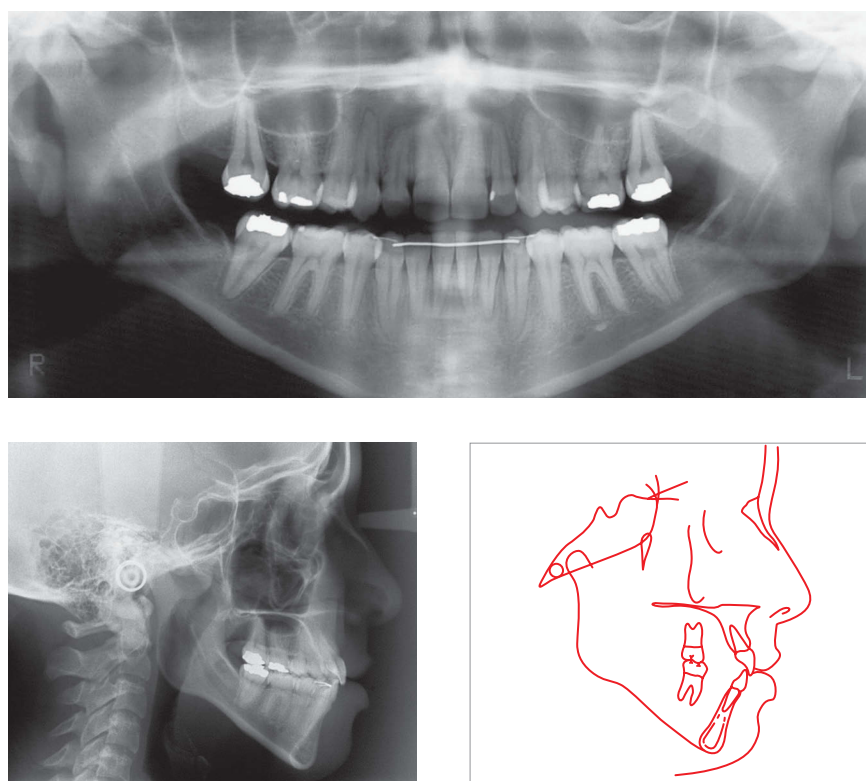


Figure 31 - Profile and panoramic radiographs, and final cephalometric tracing.

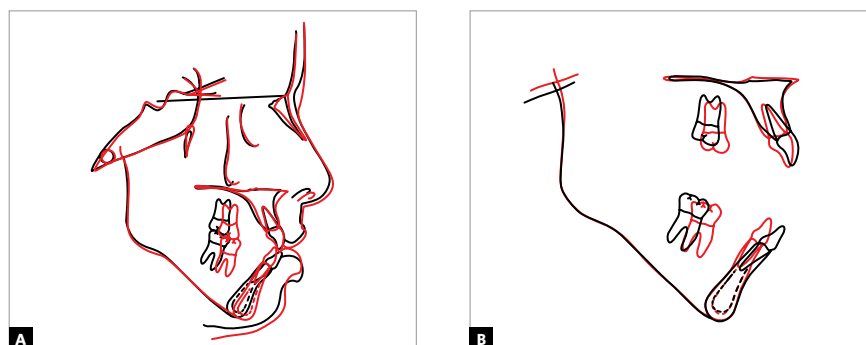


Figure 32 - **A)** Total and **B)** partial superimpositions of initial (black) and final (red) cephalometric tracings.

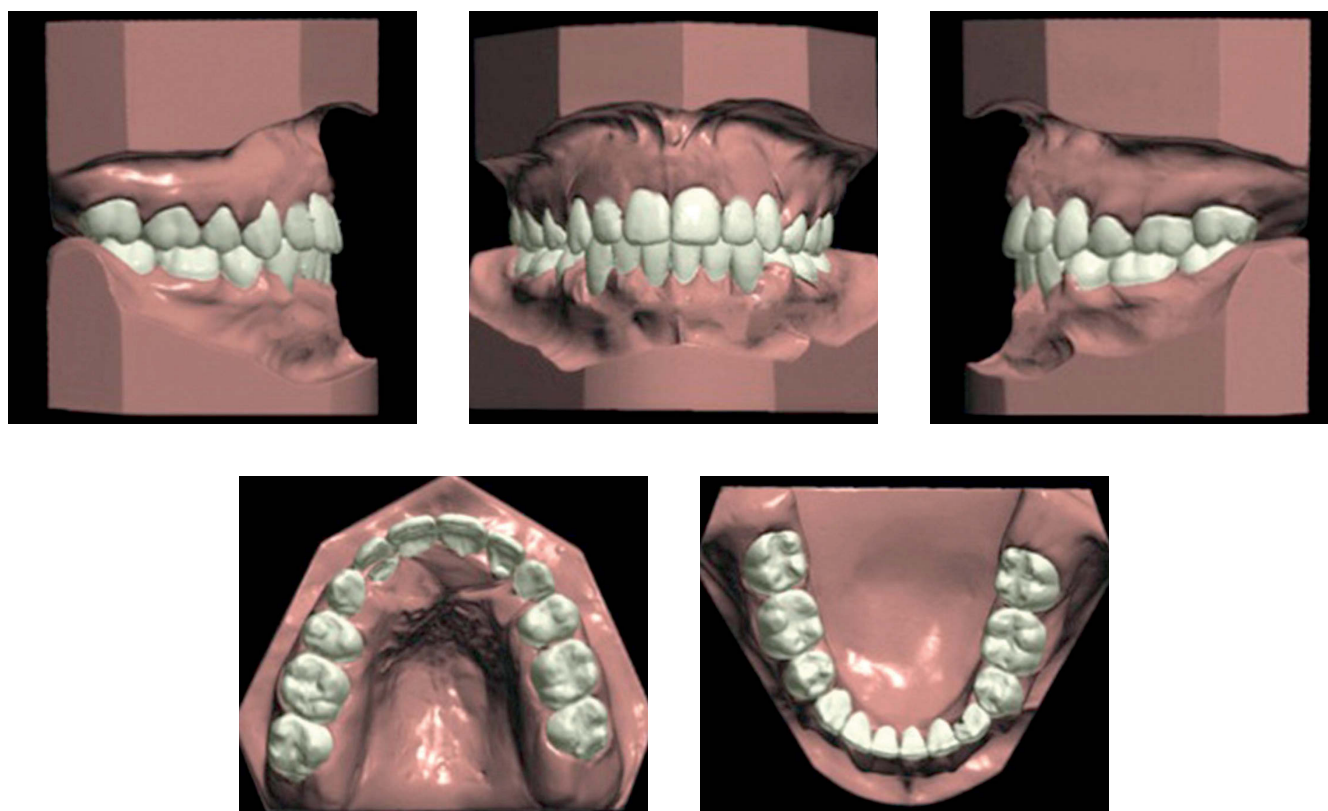


Figure 33 - Digital setup performed with OrthoAnalyzer software.

when simulating the tooth movements according to the manual setup construction method described in this article. Figure 33 shows the digital setup of one and the same patient.

Finally, a manual or digital reading of the setup is recommended, recording all information obtained

from this diagnostic simulation on a form (Fig 28), so that no information is lost and maximum benefits can be derived. As a result, treatment planning will be more reliable and prognosis more clearly envisaged, especially in more complex cases or atypical extractions.

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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:

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

Yours sincerely,

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