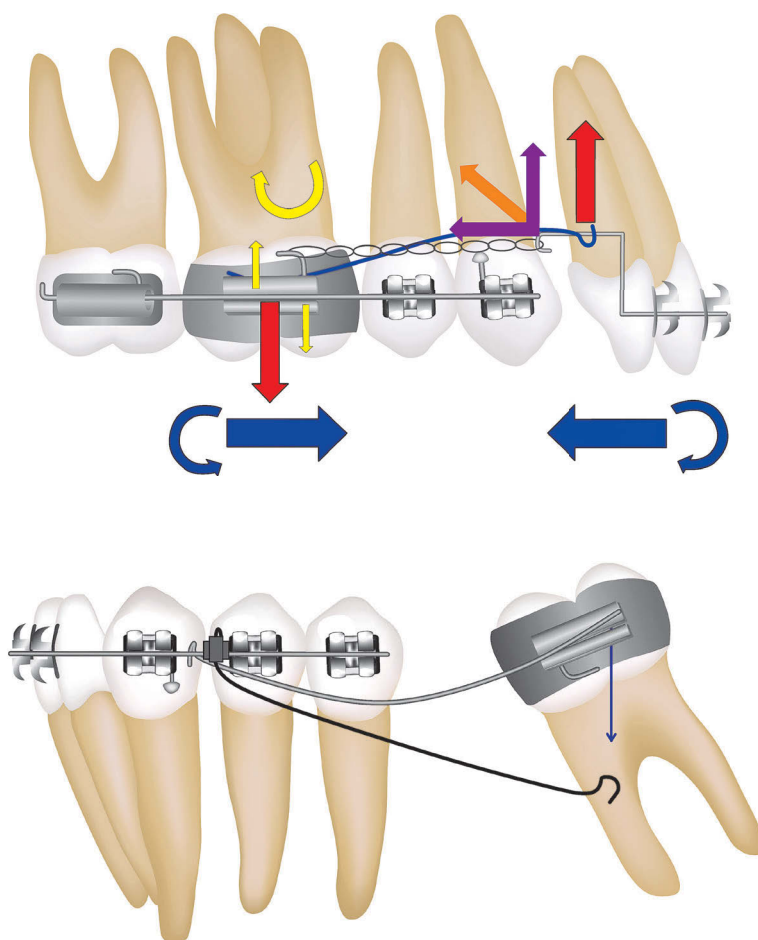




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## The Brazilian dental science

*“Men stand out for what they do; women, for what they induce men to do”.*  
(Carlos Drummond de Andrade, Brazilian poet from Minas Gerais state)

Three years ago, a sublime editorial<sup>1</sup> praised the audacious growth of Brazilian dental scientific production. At that time, our former editor dared to foresee the position Brazil would occupy in 2015: the most productive country in terms of dental scientific knowledge. The author was based on data from Scopus which, at that point, did not include *Dental Press Journal of Orthodontics* (DPJO). This database currently provides data as far as 2012, with DPJO having the highest number of scientific publications in Brazilian Dentistry.

In the current scenario, as far as 2012, Brazil still occupies the second position in world scientific production. However, we have begun to peep, as a lynx, the fact that we have come nearer the United States, the most productive country in terms of scientific production. We are growing like a giant. In 2009, for instance, the American dental scientific production was 66% greater than the Brazilian production. Nevertheless, this difference narrowed down to 20% in 2012. We should not be surprised if Brazilian scientific production reaches the first position yet in 2014, thus, corresponding to what had been wisely foreseen.<sup>1</sup> Moreover, we are certain that indexing DPJO into Scopus has contributed to accelerate such progress.

A reasonable amount of self-contemplation would reveal even more flaring indicators. Twelve years ago, in 2002, Scopus registered only 171 articles published by Brazilian authors within the field of Dentistry. In 2012, there were 1,533. Our h-index — an index that measures the impact of the scientific knowledge produced by a country, university or author — has increased exponentially. Brazil currently occupies the eighth position in the Dentistry field, which is something for Brazilian scientific production, although still young, to be proud of. Despite any criticism, improvements in this index are strongly related to government policies of closely following the scientific production of Brazilian postgraduate courses. In other words, it all resembles a conductor who perfectly leads the drum section of a samba school playing in a constant rhythm.

Furthermore, made-in-Brazil journals have significantly contributed to highlight the notorious development of Brazilian postgraduate intellectual production. Brazil currently has seven journals indexed in Scopus: In 2012, these scientific journals published 675 articles (whereas there were only two journals in 2002, with 96 articles published). At this point, you may have squinted towards a major criticism: it is only numbers. But no. Given the substantial increase in Brazilian h-index and the healthy improvements in postgraduate scientific production, this editorial is not able to list all techniques that could be employed to correct such ‘strabismus’.

In this context, Orthodontics has a lot to celebrate. In 2012, Brazil was the most productive country in terms of orthodontic publications, with DPJO — a journal indexed in the most important databases in the world — playing a major role. The h-index for Brazilian Orthodontics is the third in the world. We are certain that indexation of DPJO in PubMed/MEDLINE in 2013 will greatly contribute to future achievements.

Brazilian dental science is still simmering and, in a mathematical counterpoint, challenges the regression towards the mean. The position it has reached is a consequence of an action that involves an immeasurable number of researchers from the most secluded places of Brazil — who work overnight with passion and dedication; insane people who believe they can produce state-of-the-art scientific knowledge. Believing is a prime virtue, and that explains all the euphoria.

We have been conducted through this path by a beautiful and powerful leadership (as of a maestra): with indefatigable dedication and exhilarating inspiration — as a contagious samba that spreads itself among carnival revelers due to its sagacity. Only Drummond, in his sensibility, could perfectly describe the women of his homestate.

David Normando – editor-in-chief  
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### **SKELETAL ANCHORAGE IS A GOOD ALTERNATIVE ON THE EARLY TREATMENT OF CLASS III MALOCCLUSION**

The early treatment of Class III malocclusion is a challenge for orthodontists around the world. The challenges imposed by Biology are associated with the difficulty to obtain patient's adhesion to traditional methods of treatment: maxillary disjunction followed by maxillary protraction with facial masks. The search for alternatives to conventional treatment methods suggests that this malocclusion be corrected with intermaxillary elastics supported by skeletal anchoring plates. Despite being widely diffused in the orthodontic literature, this method requires further scientific evidence. Thus, Turkish researchers developed a clinical<sup>1</sup> study to evaluate the dental and skeletal effects of Class III malocclusion treatment performed by means of elastics placed in Class III orientation supported by intraoral miniplates (Fig 1), and the use of a facial mask associated with maxillary miniplates (Fig 2). Their results revealed

that both protocols are a good treatment option for severe Class III malocclusion. According to the authors, treatment performed with facial mask associated with miniplate is preferable for patients with severe maxillary retrusion and vertical growth pattern. However, for patients with normal growth pattern and retroclined lower incisors, miniplates associated with elastics placed in Class III orientation is a good treatment option. The authors conclude by emphasizing that, in these cases, treatment must be precisely chosen.

### **PROTOTYPED ORTHODONTIC MODELS: A GOOD OPTION FOR DIAGNOSIS AND FABRICATION OF ORTHODONTIC APPLIANCES**

The lack of space for storage, the high costs and the need for special care are the reasons why orthodontic plaster models are being substituted by digital models. Despite this tendency, some orthodontists still prefer the physical to the digital ones. The prototyping technique arose in this context.

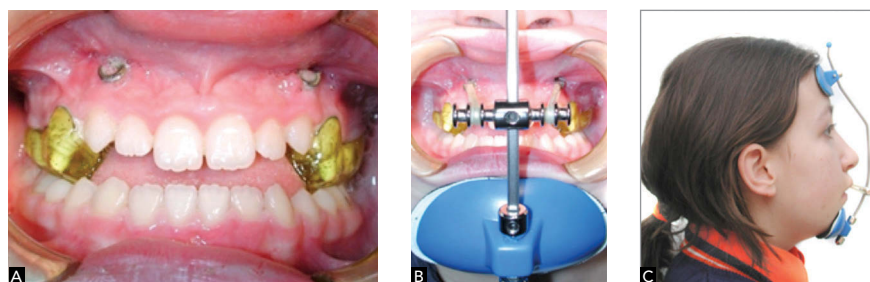


**Figure 1** - Frontal intraoral view of miniplates; **B)** Frontal extraoral view of facial mask associated with miniplates; and **C)** Patient's profile view with the use of a facial mask. (Source: Sar et al,<sup>1</sup> 2014).



**Figure 2** - Intraoral view of elastics placed in Class III orientation and miniplates placed on the symphysis and the expander appliance. (Source: Sar et al,<sup>1</sup> 2014).

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It allows digital models to be printed by 3D printers, which results in the fabrication of physical models. However, would these models have the same dimensions of real models? Would it be possible to use them for mensuration, diagnosis and fabrication of orthodontic appliances? To answer these questions, Dutch researchers developed a study<sup>2</sup> to evaluate the precision and reproducibility of three different prototyping methods: Digital light processing, jetted photopolymer and 3-dimensional printing (Fig 3). Their results revealed that orthodontic models rebuilt by means of the prototyping technique are clinically acceptable in Orthodontics. These data is of paramount importance for orthodontists, given that they encourage them to store the digital models and print the physical ones whenever necessary and without further alternations. In the near future, when 3D printers become commercially accessible, orthodontists will be able to carry out this process at their own clinical offices.

### EXTRACTION OF DECIDUOUS CANINE IS AN EFFECTIVE METHOD FOR INTERCEPTION OF PALATALLY DISPLACED PERMANENT CANINES

Impacted canines are an issue for the orthodontic practice. Orthodontic maneuvers must be performed to allow their eruption, given that intraosseous maintenance could cause problems, such as root resorption, to adjacent teeth. Finding a new way to intercept this problem minimizes major orthodontic issues. In this context, Swedish researchers conducted a randomized<sup>3</sup> controlled clinical trial in which patients with bilateral canines palatally displaced had a deciduous canine extracted on one side, with its counterpart functioning as control. Their results revealed that extraction of a deciduous canine is an efficient method in cases of palatally impacted canines. According to the authors, this procedure must be performed in younger patients. The authors emphasize the need for space maintenance on the upper arch during the observation period.

### ECTOPIC CANINES ARE MORE PERIODONTALLY COMPROMISED AFTER ORTHODONTIC MOVEMENT

As mentioned before, the interception of canine impaction prevents several orthodontic problems.

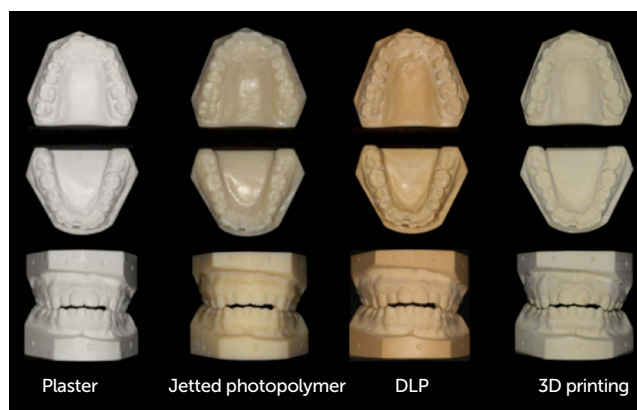


**Figure 3** - Plaster model and its corresponding replicas in occlusal and frontal view. (Source: Hazeveld et al,<sup>2</sup> 2014).

When not intercepted at a young age, treatment is only possible by extrusion with future orthodontic movement. However, what would be the periodontal and endodontic implications of this procedure? To answer this question, Turkish researchers conducted a clinical<sup>4</sup> trial in which they evaluated the periodontal health and pulp vitality of buccal and palatal ectopic canines. Their results revealed increased bacterial plaque as well as increased gingival bleeding index, pocket depth and crown length of ectopic canines. Reduction in bone level and attached gingiva were also observed. With regard to the endodontic implications, electrical tests revealed an increased threshold. Their results reinforce the need for early interception of ectopic canines, which results in better periodontal health.

### TOOTH ENAMEL COLOR CHANGES AFTER ORTHODONTIC TREATMENT

Orthodontists often have patients asking whether the color of their teeth will change after orthodontic treatment. Many patients even emphasize the question: “Doctor, will teeth bleaching be necessary after treatment?” These doubts hang in the air. What is the truth? Could we control such an undesirable effect? To answer these questions, Turkish researchers conducted a laboratory<sup>5</sup> study to test different types of bonding material associated with two different methods employed to remove remaining adhesive. Their results were, in a certain way,

frightening, given that, according to them, orthodontic treatment changes the original color of tooth enamel. Both adhesive systems and both methods used to remove them were responsible for changing

the original color of tooth enamel. It is worth emphasizing that these findings were obtained with gold-standard bonding material, therefore, extra care is necessary when using any other type of material.

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# Reasons for mini-implants failure: choosing installation site should be valued!

Alberto Consolaro<sup>1</sup>, Fábio Lourenço Romano<sup>2</sup>

Mini-implant loss is often associated with physical and mechanical aspects that result from choosing an inappropriate placement site. It is worth highlighting that:

- a) Interdental alveolar bone crests are flexible and deformable. For this reason, they may not offer the ideal absolute anchorage. The more cervical the structures, the more delicate they are, thus offering less physical support for mini-implant placement;
- b) Alveolar bone crests of triangular shape are more deformable, whereas those of rectangular shape are more flexible;
- c) The bases of the alveolar processes of the maxilla and the mandible are not flexible, for this reason, they are more likely to receive mini-implants; d) The more cervical a mini-implant is placed, the higher the risk of loss; the more apical a mini-implant is placed, the better its prognosis will be; e) 3D evaluations play a major role in planning the use of mini-implants.

Based on the aforementioned considerations, the hypotheses about mini-implant loss are as follows:

- 1) Deflection of maxillary and mandibular alveolar processes when mini-implants are more cervically placed;
- 2) Mini-implants placed too near the periodontal ligament, with normal intra-alveolar tooth movement;
- 3) Low bone density, low thickness and low alveolar bone volume;
- 4) Low alveolar cortical bone thickness;
- 5) Excessive pressure inducing trabecular bone microfracture;
- 6) Sites of higher anatomical weakness in the mandible and the maxilla;
- 7) Thicker gingival tissue not considered when choosing the mini-implant.

**Keywords:** Mini-implants. Absolute anchorage. Micro-screws. Temporary anchorage devices.

## Introduction: Mechanical interlocking is what matters!

Dental implants conceptually required months for crown placement and functional recovery. It was believed that it took weeks or months for cells to colonize the implant surface, produce matrix and mineralize it by efficient osseointegration. Science developed and now it is possible to apply a functional

load nearly immediately after implants are placed, provided that they are mechanically interlocked in a previously mineralized bone. Appropriate mechanical interlocking between implant and bone surfaces allow mini-implants to withstand masticatory forces while gradual osseointegration occurs. The type of bone and clinical condition will determine whether immediate-load implants are recommended or not.

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

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Absolute anchorage during orthodontic treatment may be obtained with mini-implants<sup>2</sup> or miniplates<sup>9</sup> placed in thick cortical bone and dense trabecular bone. Mini-implant threads must be perfectly fitted or adapted to the bone where they are inserted, allowing stability and nearly immediately withstanding the forces applied. Mini-implants are also known as micro-implants, micro-screws or anchorage screws, and comprise what is known as temporary anchorage devices (DAT).

Some specialists suggest that forces may be applied 3 days after mini-implant placement, while others recommend a waiting period of 21 or 40 days. As for immediate loading for absolute anchorage mini-implants, the waiting time is shorter — in fact, it could be immediately applied.<sup>3,12</sup>

Cortical bone thickness and trabecular bone density are important factors to be considered when determining a mini-implant placement site. Moreover, the material, surgical technique, patient's hygiene care and patient control performed by the professional are also of paramount importance.<sup>7</sup>

The main mechanism related to the efficiency of mini-implants for absolute anchorage in Orthodontics is their mechanical adaptation to previously mineralized bone structures. Such mechanism is also known as interlocking. After a few weeks or months, osseointegration, represented by cell colonization and bone formation on the surface of mini-implants, will be of secondary importance, given that, at this point, mini-implants can be removed after fulfilling their role of orthodontic anchorage.

Osseointegration is the essence of Implantodontics and is responsible for the success in the esthetic and functional recovery of lost teeth. For this reason, mechanical adaptation allows the application of immediate load within the first weeks/months. In Orthodontics, on the other hand, mechanical adaptation explains the use of mini-implants for absolute anchorage, while osseointegration is secondary and belated. Orthodontic treatment with mini-plants lasts 30% less. Furthermore, the use of such devices allow orthodontic movement to be performed without further side effects on other teeth.<sup>2</sup>

### Characteristics of mini-implants and common consequences

Osseointegration may hinder mini-implant removal and increase the risk of fracture. For this reason, mini-implants are made of titanium metal alloy, pure grade V.

In 2007, Vannet et al<sup>11</sup> placed mini-implants in dogs and histomorphometrically determined that partial osseointegration occurred in all specimens 6 months after skeletal anchorage. Mini-implants placed in thinner bone and cortical bones may require osseointegration. In these cases, titanium alloy pure grade IV is used, with acid attack on the surface of mini-implants to increase contact surface.

Thread shape and length are essential for mini-implant placement. Resistance to fracture may be improved with cone-shaped mini-implants and perforating threads. These characteristics aid dissipation of compression forces exerted by bone structures surrounding the mini-implant while it is being installed.

Mini-implant placement is simple, provided that it is carried out by skillful hands and prepared minds. On the other hand, it may offer risks when mistakenly planned and performed. According to Kyung et al<sup>6</sup> and Reynders et al,<sup>7,8</sup> mini-implant success depends on the surgeon's ability, patient's condition, appropriate placement site, initial stability, orthodontic mechanics, type of mini-implant and oral hygiene. The most frequent complications and accidents are contact between adjacent tooth roots (Fig 1), mucositis (Fig 2), contamination (Fig 3) and mini-implant fracture during placement (Fig 4) or removal. Other authors highlight that inflammation of soft tissues surrounding the mini-implant is a potential complication for TADs, which also contributes to loss of stability.<sup>4,5,10</sup>

However, one of the most frustrating consequences is mini-implant loss during absolute anchorage, when the mini-implant is dislocated and unscrewed (Fig 5). Many hypotheses try to explain the 20% rate of mini-implant loss during orthodontic treatment. This paper aims at discussing the most reasonable theories by expanding the biological and clinical knowledge gathered within Implantodontics and adapting the concepts to mini-implants and orthodontic absolute anchorage.

### Hypotheses that explain mini-implant loss during orthodontic absolute anchorage

1) Deflection of maxillary and mandibular alveolar processes and mini-implant displacement: the more apical a mini-implant is placed, the better!

The alveolar process is the portion of maxillary and mandibular bone in which teeth are suspended. It is of relatively fragile buccal and lingual thickness, with structures in continuity with the main part of the



Figure 1 - Mini-implant near the dental root.



Figure 2 - Mucositis around a mini-implant.

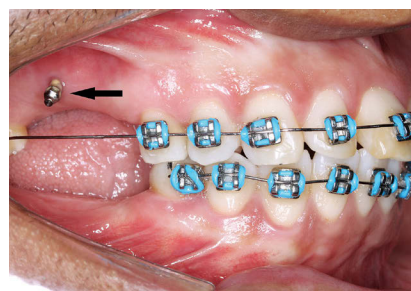


Figure 3 - Food debris around a mini-implant.

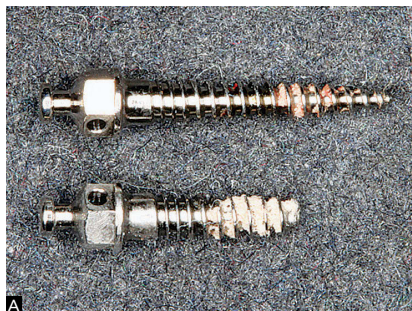
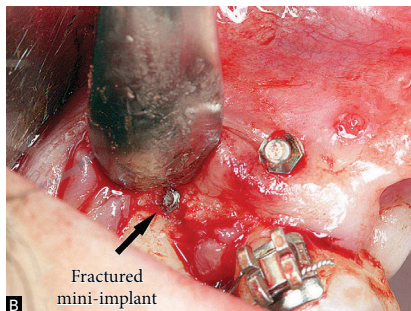


Figure 4 - Mini-implant fracture during placement.



Fractured mini-implant

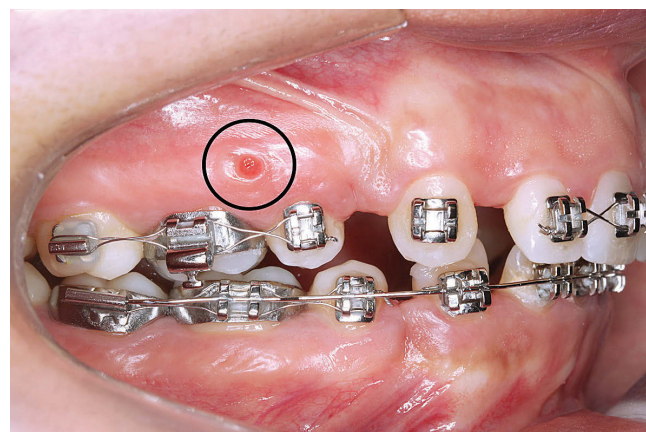


Figure 5 - Mini-implant loss.

maxilla and mandible. In an oral context, it is mostly comprised, in terms of volume, by tooth roots.

During orthodontic movement, a portion of the forces applied to the teeth promotes alveolar bone deflection. Likewise, such deflection should also occur during mini-implant anchorage, which hinders or interrupts the mechanical interlocking necessary between a mini-implant and the bone, thus, resulting in mini-implant displacement and loss.

To avoid mini-implant loss as a result of alveolar bone deflection, the device must be placed as near the

alveolar process base as possible. In other words, in the apical third of the roots where bone volume, cortical thickness as well as thicker and denser trabecular bone prevent any structural movement from happening as a result of bone deflection. Nevertheless, clinically speaking, this is not always possible, given that a mini-implant must be preferably placed in the attached gingiva in order to offer greater comfort to patients (Fig 6).<sup>2</sup>

## 2) Mini-implants placed too near the periodontal ligament with normal intra-alveolar tooth movement: Movement leads to structural lesions and inflammation!

The periodontal ligament is a specialized connective tissue fiber with 50% of its volume comprised by blood vessels. It is, on average, 0.25 mm thick. A tooth constantly leaves and enters into the socket during mastication, occlusion, swallowing, among other functions. Such intra-alveolar movements are softened and limited by periodontal collagenous and elastic fibers.

When a mini-implant is placed too near the periodontal ligament, it causes friction between a movable piece — the tooth — and a fixed piece (Fig 7),



Figure 6 - Appropriate mini-implant placement.



Figure 7 - Mini-implant placed in the periodontal ligament.

which not only causes blood vessels, cells and fibers to break, but also stimulates inflammation and, as a consequence, peri-implant bone resorption and mechanical interlocking loss.

A mini-implant must not directly touch or be placed too near a tooth due to tooth movement. Considering mini-implant position and composition, the device is not harmful to tissues. When mini-implants are placed between teeth, they must be at least 1 mm away from the roots on both sides.

### 3) Low bone density, thickness and alveolar bone volume

Mechanical interlocking, essential for a mini-implant to provide absolute anchorage, requires consistent bone structure with thick cortical plate and dense cancellous bone with thick and numerous trabeculae. In the alveolar processes, the more cervical, the thinner the cortical plates and trabeculae tend to be.

Determining the optimal site for mini-implant placement is key to success in absolute anchorage. The buccal/lingual bone structure of the alveolar process is fragile and thin. The trabecular bone may be deeply extended between roots, but its fragility remains. In short, the more apical a mini-implant is placed, the more resistant structures are available, with denser and more voluminous cortical plates and cancellous bone. Mini-implants placed near sites of recent tooth extraction represent technical difficulties and potential risks of implant loss due to low volume and low amount of bone (Fig 8).

### 4) Low alveolar cortical bone thickness

The alveolar cortical bones in the upper part of the maxilla and lower part of the mandible are much thicker. The different layers of cortical bone associated with the trabeculae from the cortical plates offer physical support as a result of interlocking with mini-implants. The closer the cortical plates are to the alveolar bone crests, the thinner they are, with the area over the teeth having the potential to present dehiscence or fenestration. It is worth reaffirming that the more apically a mini-implant is placed, the more successful absolute anchorage will be. However, we should always bear in mind that mini-implants placed on free gingiva may cause inflammation or edema as a result of tissue movement (Fig 9).

### 5) Excessive pressure and trabecular bone micro-fractures

Although mini-implants may be placed with relatively standardized forces, they may undergo overload due to excessive pressure applied by the operator during the procedure. Excess forces at mini-implant mechanical interlocking with underlying and peri-implant bone structures may lead to trabecular microfractures, peripheral and imperceptible micro-hemorrhage, and necrosis caused by the death of osteoblasts and osteocytes. Without these cells, the trabeculae and cortical bone tend to be reabsorbed by inflammation established around a mini-implant, which may result in mini-implant loss. To avoid excess pressure on alveolar bone during mini-implant placement, the specialist must apply gentle pressure so as to promote

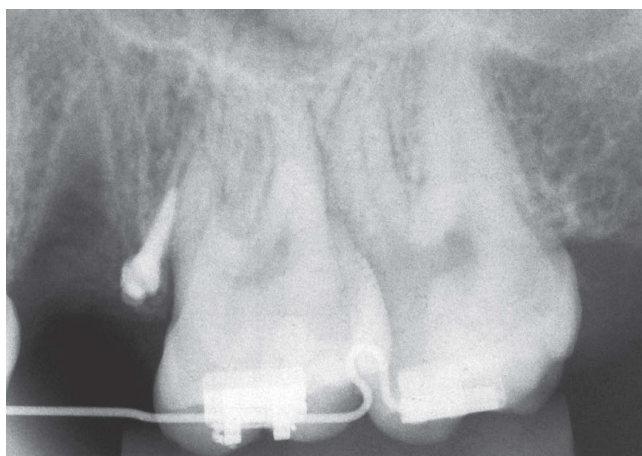


Figure 8 - Mini-implant placed in inappropriate alveolar bone.

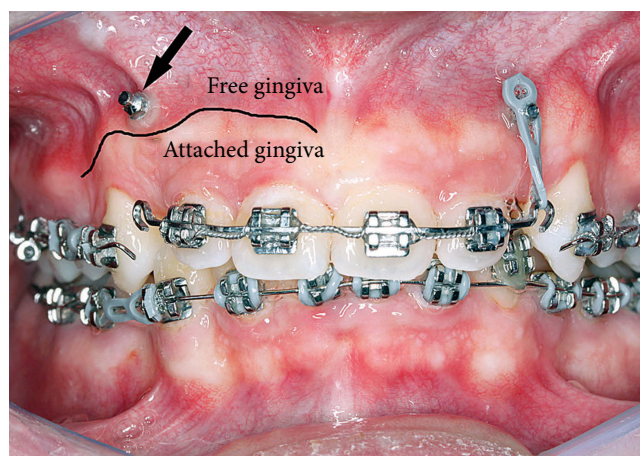


Figure 9 - Mini-implant placed in free gingiva.

the initial interlocking. Subsequently, he rotates the wrench following the direction of the thread until the mini-implant platform touches the gingival tissue.

#### 6) Sites of higher anatomical weakness in the mandible and the maxilla

The maxilla and the mandible consist of several muscles and tendons. They also hold teeth and soft tissues associated with the functions of the head and neck. Maxillary bones undergo inflammatory and reactive processes associated with periodontal disease, tooth eruption, bruxism, mastication, etc.

The anatomy of the maxilla and mandible comprise different thickness, density, volume and structures. Human maxilla and mandible vary considerably in volume, density and organization of bone structures as a result of adaptation to the specific conditions of each individual.

In the retromolar trigone, for instance, the triangular shaped area formed by two thick cortical plates located to the distal face of the second or third molar tends to be a spongy, little dense bone unable to support absolute anchorage. Should mini-implants need to be placed at this site, they must be installed at their most lingual/buccal portions, which correspond to cortical plates that are thick in width and length.

The anatomical shape of the placement site must be carefully analyzed, especially tridimensionally. In the cavity between the lateral incisor and the canine, bone

density and cortical thickness tend to be lower, similarly to recent extraction sites. The alveolar density and cortical plates of recent extraction sites are under functional remodeling, which hinders mini-implant placement in these areas (Fig 10).

#### 7) Thicker gingival tissue not considered when choosing the mini-implant

Gingival soft tissue thickness must be considered when choosing the most appropriate type of mini-implant. In cases of thicker gingival tissues, the extraosseous part of a mini-implant represents the moment arm. This requires that a larger portion of the mini-implant be deeply inserted into the underlying bone structure so as to counterbalance the extraosseous moment arm. Should this factor not be considered when choosing the mini-implant design, mini-implant loss may occur as a result of movements of the implanted bone area promoted by absolute anchorage. In these areas, transmucosal profile (2 to 4 mm) and mini-implant length must be greater.

#### Are oral bacteria, anesthesia and previous lancing procedures able to explain mini-implant loss?

Bacteria that reach tissues and mini-implants during placement are isolated. They are in low numbers and, therefore, not enough to trigger an inflammatory process that is worse than inflammation resulting from

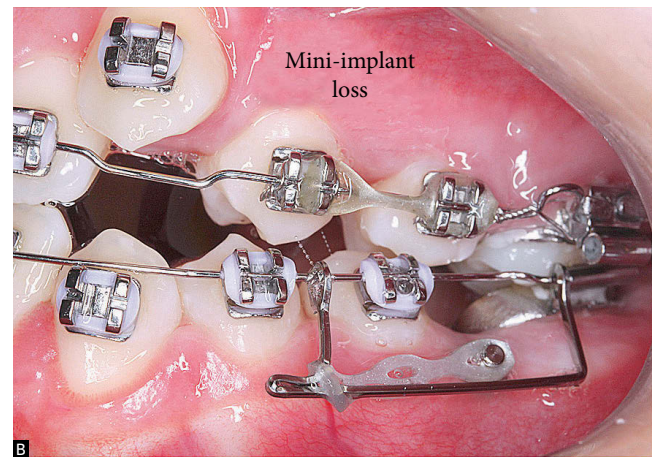
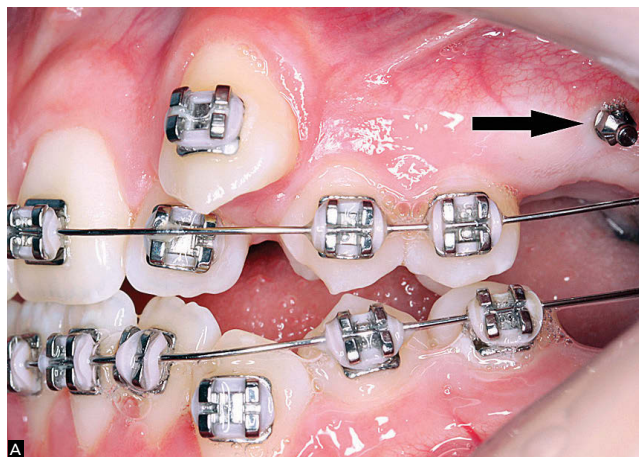


Figure 10 - Mini-implant loss due to placement in recent extraction site.

surgical procedures. Bacteria isolated from microbial biofilms are easily controlled by phagocytosis and destroyed by inflammatory exudate and infiltrate. Alone, they are not able to trigger inflammatory processes or consequential bone resorption that could lead to mini-implant loss. These bacteria are the same that cause periodontal disease; however, they do not promote mucositis or peri-implantitis in conventional implants either, provided that they do not form microbial biofilms. In 2013, Andruccioli<sup>1</sup> conducted an *in vivo* study to assess microbial contamination by using DNA probes for 40 species of bacteria and the molecular biology technique of Checkerboard DNA-DNA hybridization. Bacterial endotoxin and inflammatory cytokines found in lost mini-implants were also used. The author concluded that microbial contamination and the amount of endotoxin found in the mini-implants did not act as a determining factor for loss of stability.

### Final considerations: Mini-implant loss is associated with the placement site!

The biology of cells and bacteria do not explain mini-implant loss. Our cells as well as our immune system readily accept titanium alloys, as reported by many researches. As for bacteria, they are the same of our microbiota. Thus, when they reach a tissue, they are soon defeated, as microbiota bacteria are. Mini-implant loss is often associated with physical

and mechanical aspects that result from choosing an inappropriate placement site.

It is worth highlighting that:

- 1) Interdental alveolar bone crests are flexible and deformable. For this reason, they have little mobility to offer and may not provide the ideal absolute anchorage. The more cervical the structures, the more delicate they are, thus offering less mechanical interlocking for mini-implant placement.
- 2) Alveolar bone crests of triangular shape are more deformable, whereas those of rectangular shape are more flexible.
- 3) The bases of alveolar processes of the maxilla and the mandible are not flexible, for this reason, they are more likely to receive mini-implants.
- 4) The more cervical a mini-implant is placed, the higher the risk of loss. The more apical a mini-implant is placed, the better its prognosis will be.
- 5) Before mini-implant placement, it is advisable that a 3D analysis be carried out on the site by means of periapical radiographs, particularly by bisection and interproximal techniques, and occlusal radiograph with periapical film. Volumetric computed tomography with its several evaluation slices may replace conventional radiography.

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## Error of the method: what is it for?

Rodrigo Hermont Cançado<sup>1</sup>, José Roberto Pereira Lauris<sup>2</sup>

The aim of this paper is to demonstrate the importance of evaluating the error of the method in Orthodontic scientific studies. Special emphasis will be given to the scientific importance and the different types of the error of the method (systematic and casual), the statistical tests most commonly used to quantify these errors and the clinical meaning of the error of the method for the interpretation of results obtained from orthodontic treatment.

To conduct studies within the Dentistry field, particularly in Orthodontics, the researcher needs to measure continuous quantitative variables, i.e., angles or millimetric distances (for instance, the cephalometric variables of lateral cephalograms and/or variables of study casts). To analyze a lateral cephalogram, cephalometric points are traced and distances and angles are measured. However, it is known that these values will vary between examiners and for the same examiner at different moments. It is difficult to obtain always the same exact value. Thus, most studies do not provide accurate measurements with 100% reliability. Because the variability of measurements, that is, the “errors” will always exist, the magnitude and source of errors are more important than the errors themselves.<sup>2</sup> In scientific research, measurement without the information on the magnitude of the error makes no sense. Therefore, it is extremely important not only to determine the examiner’s accuracy in obtaining measurements, but also to estimate all possible sources of error in a research.

A recently published study identified the 100 most cited articles in the orthodontic literature between 1975 and 2011.<sup>4</sup> At the top of that list, with 545 citations, is the study conducted by Houston,<sup>3</sup> which aimed at performing error analysis for the measurements carried out in orthodontic research. This fact highlights the importance of the error of the method for orthodontic research.

The main source of measurement error in Orthodontics is the interference of the examiner in the measurement process. While the examiner does not interfere in the process of measuring a person’s weight (because it is enough just to put the individual onto a scale), cephalometry depends on his knowledge and ability to locate the cephalometric points. Ideally, the methods employed should be accurate enough so as to allow their reproduction. When this accuracy is somehow compromised, errors occur. They can be defined as the difference between the value obtained during the process of measurement and the real value of the magnitude of measurement.<sup>5</sup> These errors, when significant and of great magnitude, affect the reliability of results by increasing or decreasing the real differences among the studied variables. The most common types of errors of scientific methods are the casual and systematic error.<sup>3</sup>

The casual error, also known as random error, occurs due to the difficulty and/or inaccuracy in either identifying or defining certain points. The systematic error, also known as non-random error, occurs when a given

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measurement is continuously under or super-estimated. If a single examiner makes the measurement, generally, this type of error results from either a modification in the measurement technique or an unconscious bias towards directing the outcomes according to his/her own expectations.<sup>3</sup> Systematic errors of great magnitude distort the results towards a certain direction, while random errors of great magnitude imply difficulty in reproducing the measurements, leading to question either the validity of the method or the examiner's ability.

To obtain the magnitude of casual and systematic errors, that is, the examiner's accuracy in performing measurements, it is necessary to make new measurements on the material used in agreement with the methods employed. A sufficient number of cases must be measured again; otherwise, only great systematic errors will be identified. Empirically speaking, it is believed that repeating 20% of the measurements is enough; but this is not always the truth. If a study sample comprises 15 patients, repeating the measurements of only three individual is not enough. On the other hand, in a study comprising 500 individuals, it is not necessary to repeat the measurements of 100 patients. The required number partly depends on the standard deviation of the differences between the first and second measurements; however at least 25 cases should be measured again.<sup>3</sup>

Repetition of measurements should be carried out by the same examiner: the so-called intra-examiner error. When measurements are performed by two or more examiners, they must repeat the measurements to calculate the intra-examiner and inter-examiner error, that is, the variability of measurements between examiners. In a scientific research, measurements are taken by two or more examiners for different reasons, but normally, the aim is to demonstrate the reliability and reproducibility of the measurement method.

Systematic errors can be identified by means of many statistical tests, for example, paired t-test, the intraclass correlation, and even the Bland-Altman method. Statistically significant differences indicate the presence of systematic error. A good measurement method should not reveal statistically significant systematic error; however, if we consider that in cephalometry the amount of variables is very large, the significant systematic error is expected in about 5% of the cephalometric variables. For example, if a study comprising 30 cephalometric variables reveals significant systematic error in two of

them, this result would be expected, and the method should not be revised.

In cephalometry, one of the methods most commonly used to estimate the magnitude of random errors is that proposed by Dahlberg's formula.<sup>1</sup> It is not a test of significance, but an evaluation of which is the typical difference between the real measurement and the measurement obtained by the method. Thus, this error is expressed in millimeters or degrees, depending on the measurement unit of the variable. Naturally, measurements involving cephalometric points of difficult visualization and identification show greater casual error. No objective rule states how many millimeters or degrees of casual error would be acceptable, because this depends on the interpretation of the measurement. Many authors claim that errors in linear measurements not greater than 1 mm and angular measurements not greater than 1.5° are acceptable. It is important to remember that the casual error is the estimate of the error when one factor is evaluated. Because these studies comprise samples of many factors, the error of the mean of individuals is smaller than that of the individual error.

In summary, whenever a study involves measurements that depend on the examiner's knowledge and ability, it is important to control the error of the method to demonstrate the reliability and reproducibility of the results obtained — indispensable characteristics of scientific knowledge.

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An interview with

# Marissa C. Keesler



Dr. Marissa Keesler attended dental school at Creighton University in Omaha, Nebraska and in 1987 received her Doctor of Dental Surgery degree with high honors. In 1989, she graduated from Marquette University with a Certificate and Master of Science degree in Orthodontics. Dr. Keesler has been an Adjunct Professor in the Marquette Graduate Orthodontic Department since 1990 and has been a guest speaker at several universities and orthodontic groups nationally and internationally. She has contributed to the development of several orthodontic textbooks in topics related to multidisciplinary treatment and the indirect bonding technique. Dr. Keesler is a member of the American Association of Orthodontists and many other local and national dental and orthodontic societies such as the Edward H. Angle Society of Orthodontists and the Pierre Fauchard Academy. She also has Diplomate status with the American Board of Orthodontics and is a graduate of the AEO Roth/Williams Center. Dr. Keesler has been in specialty practice since 1989 and has had a full-time private practice in Neenah since 1992. In 2000, she was joined by her husband, Dr. Jeffrey T. Keesler, who has a dual specialty in Prosthodontics and Orthodontics.

Dr. Roberto Lima Filho

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

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## What differences in treatment efficiency do you notice in your clinical practice between patients who undergo 2 -phase treatment and those who do not? [Fernanda Catharino](#)

The question that I routinely ask myself when determining whether early orthodontic treatment should be considered or not is, "Can the problems presented by this young patient worsen as we wait for the rest of the deciduous teeth to exfoliate? Or, can they remain the same or perhaps even improve naturally?" If it is the first of the two, then early treatment is recommended. Some of the problems corrected during this first phase may include moderate to severe crowding, deleterious habits (e.g., thumb or tongue), ectopic eruption of certain permanent teeth (e.g., maxillary first permanent molars), crossbite of permanent teeth, and functional crossbite of deciduous teeth. I try to time the start of all Phase I treatments adequately so that the duration can be kept within one year or less. Parents are made aware that after all the permanent teeth erupt, new diagnostic records will be gathered to determine the need for a second phase of treatment. If indicated, Phase II can oftentimes last anywhere between 12-18 months depending on the malocclusion and skeletal discrepancies remaining.

If a single phase of comprehensive treatment is more advisable for the young patient, growth and development is monitored every 6-12 months until all the permanent teeth have erupted, including the second molars. Waiting until the second molars erupt to start comprehensive treatment will ensure that any eruption and torque problems presented by these teeth can be addressed immediately and that treatment will progress quickly without having to scale back down in archwire size later, or have to do additional treatment in the future. Comprehensive therapy can last anywhere between 12-24 months depending on the severity of the problems.

While it is true that a single phase of treatment may seem more efficient in terms of cost and the final sum of treatment time, I believe that there are many cases where the final outcome, including facial and dental aesthetics and periodontal health, can be more ideal with two phases of treatment.

## Regarding the effects of early intervention on jaw growth, what is the optimal time to start treatment in Class II patients? [Fernanda Catharino](#)

I mostly tend to use the dentitional stage (late mixed or early permanent dentition) to determine the optimal time to start Class II therapy.

I also follow the cervical vertebra maturation (CVM) method developed by Don Lamparski<sup>1,2</sup> and advocated by Jim McNamara. The maturational stage is determined by the level of cervical vertebra maturation observed in the lateral headfilm and the most effective time seems to be during the circumpubertal growth period.

Most of the time, if the discrepancy in centric relation is less than half a tooth, a headgear will be considered. Those that are end-to-end or larger are usually treated with a fixed Herbst appliance, keeping in mind that most studies have shown that the treatment effect produced by this tooth-borne type of functional appliance is 50% dental and 50% skeletal.<sup>3,4</sup> Careful attention is also paid to cephalometric evaluations that indicate whether mandibular growth will be favorable or not (e.g., Jarabak's upper and lower gonial angles, and mandibular corpus length).<sup>5</sup> When Class II skeletal discrepancy is severe and mandibular growth is not favorable, growth and development is monitored and surgical-orthodontic treatment is suggested after the patient has matured skeletally.

If the patient presents a severe Class II that may be affecting his or her self-image or self-esteem, intervention may be done earlier with everyone's understanding (including patient, parents, and referring dentist) that comprehensive treatment will still be necessary later and that this may include orthognathic surgery.

## What are the main aspects that should be observed in the finalization of orthodontic treatment that, in your opinion, contribute to long-term stability? [Fernanda Catharino](#)

While it may be argued whether non-ideal occlusal relationships have an impact on the dentition,<sup>6</sup> it is my personal opinion, after evaluating our finished cases, that long-term stability can be influenced by the attainment of an ideal functional occlusion, the amount of CR/CO discrepancy remaining, and the amount of occlusal detailing that is accomplished by the end of treatment. Excellent bracket placement since the start of treatment will minimize archwire bends or rebonds, thus reducing the amount of roundtripping of the teeth as well as the treatment time. A good retention protocol is also an important factor contributing to the long-term stability of results.

**A problem faced by many clinicians during the indirect bonding technique is the excess resin around the brackets. How can this problem be avoided in the bonding technique you use?**

Fernanda Catharino

The Indirect Bonding technique is a very sensitive procedure. For this reason, special attention should be paid to every step so that ideal results can be routinely achieved. The following is the protocol used in our practice for bracket placement on working casts.

Using a thin black lead pencil, such as a 0.03 mm Pentel™ pencil, the long axis and marginal ridges of the teeth are drawn on dry working casts. A marking is done 2 mm below the marginal ridge line on all posterior teeth indicating the position of each bracket slot. A bow divider (Dentraurium™) and a millimetric ruler are used to determine the 2 mm marking. This will ensure that all marginal ridges will be leveled at the end of treatment. In the mandibular arch, the distance from the bracket slots to the cusp tips of the first bicuspid is transferred to all the incisors and 0.5 mm is added for the canines. In the maxillary arch, the distance from the bracket slots to the cusp tips of the first bicuspid is transferred to the lateral incisors and 0.5 mm is added for the centrals and the canines.

Two thin coats of a mix of separating medium and water in a 1:6 ratio are applied to the casts and let dry for 5 minutes. A light-cured composite, such as Transbond XT™ (3M Unitek), is placed on the mesh pad of each individual bracket to create the custom base. The brackets are then placed on the working casts. It is important that each bracket is placed as accurately as possible right away to minimize the amount of repositioning done before the composite is cured, thus, maintaining the integrity of the composite custom bases. The brackets are positioned and the excess resin is removed around the periphery of each bracket with the aid of a Hollenbach instrument. The casts are then placed in a Triad™ 2000 light curing unit for 5 minutes.

There are several different ways in which the custom transfer trays can be fabricated. After trying many different tray systems over the past 26 years (including the two years in my residency program at Marquette University), I have concluded that the dual tray system provides the most accurate results in a consistent manner. A coating of an effective separating medium,

such as General Purpose Silicone Mold Release or PAM cooking spray, is sprayed over the casts and brackets and a soft, 1.5 mm sheet of clear Bioplast™ material is then vacu-formed over the bracketed casts in a Biostar™ machine (Great Lakes Orthodontics). The excess material is trimmed using a pair of small scissors. Another coating of separating medium is sprayed over the outer surface of the Bioplast tray and a 1-mm thick layer of Biocryl is then vacu-formed over the soft tray in the Biostar. The separating medium prevents adhesion and allows customization of the two trays. The excess Biocryl material is trimmed with small scissors and the outline of the tray is cut using a slow speed handpiece cutting disc. The cast is submerged in water for approximately 10–15 minutes. The trays containing the brackets are removed from the casts with the aid of a plaster knife and are immediately placed in the Triad unit for an additional 1 minute with the brackets facing upward. The custom resin bases are then micro-etched very lightly with 50-micron aluminum oxide to clean them and to permit a good bond. As a general rule, 1–2 seconds should be enough, making sure that some of the resin is not abraded away. The excess aluminum oxide is removed from the bracket bases using compressed air. The bases are then cleaned with a hand-held steam cleaner. After drying thoroughly, a straight bur on a high speed handpiece is used to remove any excess composite around the periphery of each bracket (Fig 1). The trays are separated and the soft tray is trimmed with small scissors and the hard tray with a sharp Bard-Parker knife. The soft Bioplast tray must extend to the gingival margin, whereas the hard Biocryl tray needs to extend only as far as the bracket slots. The areas around the bracket hooks are relieved on the soft tray by making a simple cut next to each hook with small sharp scissors to allow for easy removal of the tray during the clinical procedure. The soft and hard trays are then put back together.

The protocol used in our practice for the chair-side bonding procedure is as follows:

After all the tooth surfaces to be bonded are well cleaned, each custom bracket base is prepared with Assure® Universal Bonding Resin (Reliance Orthodontic Products). A thin line of flowable adhesive is applied along the gingival edge of each molar bracket custom resin base, and a small dot is made on the middle area of the gingival edge from second

bicuspid to second bicuspid (Fig 2). The prepared indirect bonding trays are placed under a light protective box until they are ready to be placed over the teeth. The oral cavity is well isolated using NeoDrys™, the cheek retractor portion of the Nola Dry Field System (Great Lakes Orthodontics, Ltd.), and the tongue shield portion of the Quest™ Dry Field System (Ortho Quest). The teeth are dried thoroughly. The facial surfaces of all teeth to be bonded are etched on one arch using a viscous liquid or gel 37 or 40% phosphoric acid for 15 to 30 seconds followed by thorough rinsing. Each tooth is well dried using a warm air tooth dryer. Using a brush, a thin layer of Assure Universal Bonding Resin is applied to the etched enamel. The advantage of this moisture insensitive primer is that it can be used on most any surface. The tray is then seated and each tooth is cured for 10 seconds using either a high intensity halogen or LED curing light, or 5 to 10 seconds with an argon laser. The procedure is repeated for the opposite arch. The hard outer tray is removed easily and the soft inner tray is removed with the aid of a scaler to peel away the material from around each bracket wing.

If all the steps are carried out carefully, the amount of adhesive flash remaining around the brackets at the end of the procedure should be minimal to none and can be easily removed with a scaler (Fig 3).

**In your clinical experience, what are the advantages (besides hygiene) for the use of self-ligating brackets compared to conventional appliances?** [Luciana Closs](#)

We have used the self-ligating bracket system in our practice for approximately 14 years, and we have been able to experience several advantages that have an impact in the quality of our treatment results compared to the use of conventional brackets. The most important, in my opinion, is the ability to obtain full expression of each bracket prescription with the use of larger stainless steel archwires which can be engaged with ease using “active” self-ligating brackets. A routine sequence of archwires in our practice may consist of: 0.014 NiTi, 0.019x0.025-in BioForce® (Dentsply GAC), 0.019x0.025-in stainless steel, and 0.022x0.028-in stainless steel. It will be difficult to engage and close the doors on every bracket with a larger archwire if



**Figure 1** - A straight bur on a high speed handpiece can be used to remove any excess composite around the periphery of the custom resin.



**Figure 2** - Flowable adhesive is applied along the gingival edges of each custom resin base, a line on the molars and a dot on the rest from second bicuspid to second bicuspid.

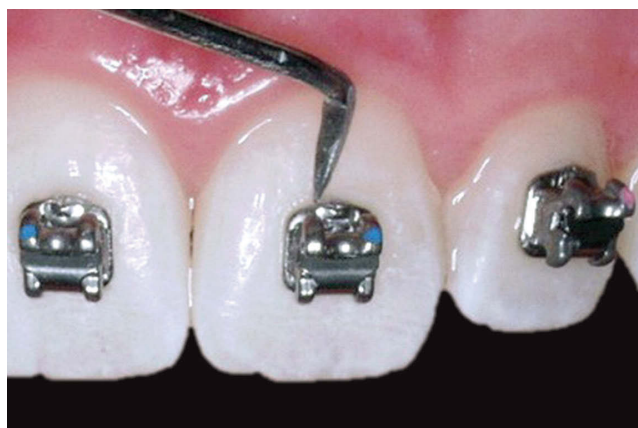


**Figure 3** - If each step is carried out carefully, minimal to no adhesive flash should remain around each bracket at the end of the indirect bonding procedure.

the previous one has not been allowed enough time to fully express itself. If this happens, the previous wire will need to be kept in longer or a smaller jump in size of archwire would need to be considered.

In our practice, ideal finished results with proper torque and rotational corrections are consistently obtained using “active” self-ligating brackets without having to rely on the use of steel ties.

These types of brackets and the use of the indirect bonding technique are two important tools that allow us to obtain excellent tooth positions in a reliable and consistent manner.

**What is your protocol for retention? Would you recommend the long-term use of a bonded 3-to-3, based on the risk of ankylosis of the bonded teeth?** [Luciana Closs](#)

Our protocol for retention consists of the following: a couple of months prior to the end of treatment, CR mounted models are taken to evaluate the occlusion and each individual tooth position in all three dimensions. If minimal additional adjustments are necessary, these are carried out and the same mounted models are sent to a commercial laboratory for the fabrication of a CR tooth positioner. If a mandibular fixed 3-to-3 lingual retainer is part of the retention plan, perhaps due to severe pre-treatment dental rotations or large diastemas, an impression is taken one week prior to removal of the fixed appliances for its fabrication. At the debond appointment, the fixed retainer is indirectly bonded first, followed by bracket and composite removal and aesthetic enhancements. The CR tooth positioner is tried in and instructions are given to the patient (wear full time for the first 4 days followed by 4 hours plus nights for 7 weeks). At the following appointment, post-treatment records are taken as well as an impression for maxillary and mandibular removable retainers. Most of the time, the upper is a clear plastic retainer that will also protect the teeth from any mild clenching or grinding habits. If rapid palatal expansion was part of the treatment, a maxillary wrap around retainer is fabricated instead. A spring aligner is used as the lower removable retainer. The teeth should settle for the most part with the positioner, so the patient is instructed to wear the removable retainers 12 hours every night as soon as they are delivered.

If a mandibular fixed retainer is used, it is left in place for at least 2 years, or until the status of the third molars is determined in adolescents. After this, the patient is given the option of keeping the fixed retainer in place for an indefinite period of time, or of having it replaced with a spring aligner. Almost always, patients will choose to keep the fixed retainer. The option is not offered when calculus tends to build-up easily around the wire. In this case, the fixed retainer is removed automatically and replaced with a removable retainer after 2 years of retention, or prior if the general dentist recommends it.

In my experience, I have never really observed any true ankylosis of bonded teeth being caused by the long-term use of a fixed 3-to-3 retainer. What I have observed, in certain cases, is the relapse of an open bite or of an impacted tooth become more noticeable when the teeth previously affected are splinted together with a fixed retainer.

**What are the indications for Invisalign in your practice and how do you feel about it in finishing your cases?** [Luciana Closs](#)

Even though Invisalign is available in our practice, it is not routinely my treatment of choice unless it is the only option the patient wants to consider (mostly adults) and I determine that he or she is an appropriate candidate. I will consider Invisalign only in cases with minor crowding or spacing and where occlusal or skeletal discrepancies are not necessary or expected to be corrected.

With the techniques that we employ in our practice, I have never felt the need to consider Invisalign or other computer-based systems to finish any of my cases. After taking a progress panoramic radiograph to re-evaluate tooth positions mid-treatment, if it is determined that additional detailing is necessary, it will be done with bracket repositions. If the brackets are properly placed on each tooth and an appropriate bracket system is used, every case should be able to be finished with a straight wire using the straight-wire appliance (Fig 4).<sup>7,8</sup>

**What are the tools you use to get compliance during treatment and post-treatment (For instance, the use of elastics and retainers)?**

[Luciana Closs](#)

Good communication and accurate documentation is another aspect of our practice that is critical to achieve our treatment goals and to meet everyone's expectations.

Initially, it is imperative to gather accurate information and records, which will yield the best diagnosis and treatment plan for the patient. Stephen Covey, in his highly acclaimed book *The Seven Habits of Highly Successful People*, suggests that we “Begin with the end in mind”. While this is great advice for any endeavor, it is fundamental to orthodontic care. Before treatment is initiated, it is important to have a clear understanding of what the outcome should be to design appropriate treatment goals and be able to share these with the patient, parents, and referring dentist.

A thorough explanation of the importance of the elastics and retainers and possible repercussion with poor cooperation, should be part of the information given to the patient at the time when these appliances are introduced. If poor compliance is detected and addressed and no improvements are noticed up to a couple of appointments after, it is part of our practice policy to immediately take intraoral photographs and share these with the patient and parents during a private consultation at the end of the appointment. Improvements that have been achieved up until then are pointed out and the remaining work necessary to finish treatment is discussed as well as the challenges presented by the lack of cooperation. A time frame to demonstrate improvement is given to the patient. If no changes are observed after the time stipulated, braces are removed and a maxillary splint retainer is given to the patient to be worn every night for an indefinite period of time. The splint will help to protect the teeth and joints and compensate for the remaining malocclusion until the patient decides later in life if he or she wants to have the treatment completed. The cooperation consultation also gives us the opportunity to analyze the family’s commitment and desire to continue striving for ideal results. If a negative attitude is observed, removal of the braces is suggested right away as the best alternative to prevent irreversible damages from occurring and additional time from being wasted.

Very few of these consultations are necessary in our practice given that we always try to be proactive instead of reactive from the start of treatment. An excellent diagnosis stemming from the gathering of accurate pre-treatment records can also prevent us from erroneously accusing patients of not cooperating when results are not being observed with certain appliances, such as

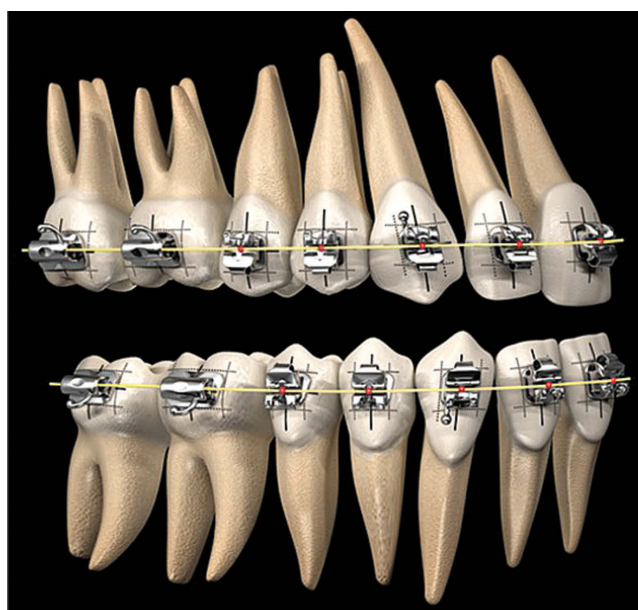


**Figure 4 - Andrews® Plane:** The surface or plane on which the mid transverse plane of every crown in an arch will fall when the teeth are optimally positioned. This plane virtually connects the appliance through the FA point.

elastics or headgears, when more likely it could be due to a misdiagnosis and trying to do the impossible.

It is also important to maintain good communication with the referring dentist.

In the 1980’s, the sociologist/futurist Avrom King postulated that fine Dentistry was behaviorally self-limited. King meant that regardless of the dentist’s technical expertise, unless he or she had the requisite behavioral skills to communicate, including the ability to profoundly listen to his patients and then motivate them, his technical skills would go largely unused.<sup>9</sup>

**Considering the exceptional quality of your finished cases, we would like to know if besides the indirect mounting of brackets, you use some other gimmick at the debonding stage.**

**Nelson Mucha**

In my opinion, some of the most important technical aspects that help us to obtain good quality results include: the use of the indirect bonding technique and self-ligating brackets, CR mountings of diagnostic models, evaluating the coordination of upper and lower archwires at each appointment, and the use of centric relation tooth positioners immediately after debond.

If it has not already been done at some point during treatment, the incisal edges of the maxillary and mandibular incisors are reviewed and equilibrated close to debond to confirm that these teeth are at proper vertical heights and that they follow the patient's smile arc. If severe incisal fractures are present, the recommendation for restorations is done immediately following tooth positioner wear. Any type of build-ups of small teeth, such as peg lateral incisors, are done as soon as enough space has been created mesial and distal to these teeth to avoid the need for prolonged use of coil springs.

**Still in relation to finishing, do you use a special procedure sequence or a check list before debonding? If so, what or where would they be?**

Nelson Mucha

Midway through treatment and prior to the initial placement of a rectangular stainless steel archwire, a progress panoramic radiograph is taken to evaluate root positioning and angulations of the teeth. Keeping in mind the possibility of radiographic distortions, this x-ray is used simply as a guide to decide whether certain brackets need to be repositioned. When it is determined that the patient is ready for debond, a series of appointments are scheduled. The first one consists of an appointment to gather impressions, a hinge axis, and a power centric bite for the fabrication of a tooth positioner. At a second appointment, impressions are taken for any fixed retainers indicated. The last of the series of appointments takes place a week later for the actual debond. The fixed lingual retainers are placed also by means of the indirect bonding technique. Brackets are removed and the CR tooth positioner is tried in and delivered.

The centric relation mounted models gathered for the fabrication of the tooth positioner also allows us the opportunity to do a final evaluation of each tooth prior to debond. Most of the time, no additional adjustments are necessary at this point, otherwise, they are done at the following appointment when the impressions for the fixed lingual retainers are taken. If major discrepancies are noticed, appointments may be reevaluated and discussed with the patient for re-scheduling. At this stage, we will also check that all of our treatment goals, including facial aesthetics, dental aesthetics, functional occlusion, periodontal health, and healthy temporomandibular joints, have been achieved.<sup>10</sup>

**What is the need for anatomical tooth reshaping or occlusal adjustments during the finishing procedure? If there is a need, what procedures are used?** Nelson Mucha

Anatomical reshaping or occlusal equilibration, when properly done, can be an important step to further enhance the finished orthodontic results.<sup>11</sup> It allows the reduction of any remaining CO-CR discrepancy, thus increasing stability of results. Occlusal equilibrations are not always possible to do on every finished comprehensive case, perhaps because the patient may not want to invest any more time and money into their treatment, or because the general dentist may not feel confident enough to perform the procedure. Whenever possible, it is carried out on all non-growing patients post-orthodontics and after the occlusion has settled.

When occlusal equilibration is indicated, the patient is placed on a CR splint (preferably maxillary) full-time for a minimum of 3 months to deprogram the muscles. Centric relation records are taken post-splint and the teeth on the models are painted using any red water based paint. A preliminary equilibration is done on these casts (Fig 5A, 5B). The white stone will show up on the areas that have been filed making it easier to recognize them with articulating paper in the patient's mouth so the adjustments can be duplicated. After the equilibration is completed, new CR articulated working casts are gathered and the steps are repeated once or twice more. The patient continues to wear the splint full-time during this time. When all balancing interferences are eliminated, the patient is instructed to wear the splint at night. There are times when negative coronoplasty is not enough to restore the patient back to an ideal functional occlusion and positive coronoplasty, i.e., restoration of teeth may also need to be considered on some of the anterior teeth. "Mastery simply requires we go beyond our limitations to produce results beyond the ordinary." Avrom King.

**As we learn from your lectures, we can see your great knowledge in relation to diagnostic procedures and treatment planning, especially regarding the numerous cephalometric analyses used. Seeking to summarize all this information, which cephalometric data or diagnostic criteria do you consider more important or more**

# **relevant for a proper diagnosis and consequently to treatment success?** Nelson Mucha

The gathering of quality initial records is important to precisely diagnose, create optimal treatment plans and complete those treatment plans efficiently and effectively. There are times when the patient may not be able or willing to go ahead with the ideal treatment plan recommended (e.g., orthognathic surgery), but it is important to properly inform the patient and be able to offer alternate treatment options with the understanding that the occlusal problems may be improved, but not totally corrected and that a splint may be necessary as an indefinite night retainer to protect

the teeth and joints. With all the information being clear to everyone and the expectations being kept consistent, treatment can be carried out efficiently and effectively in the least amount of time possible.

The initial records routinely collected in our practice consist of panoramic and cephalometric radiographs, facial and intraoral digital photographs, CR articulated models, and a CT scan in cases with skeletal asymmetries or where the panoramic radiograph may have indicated anomalies or eruption problems (e.g., impacted or supernumerary teeth). Cephalometric analyses, such as Steinert, Ricketts, and Jarabak, are done, as well as a Visual Treatment Objective (VTO). A VTO will allow

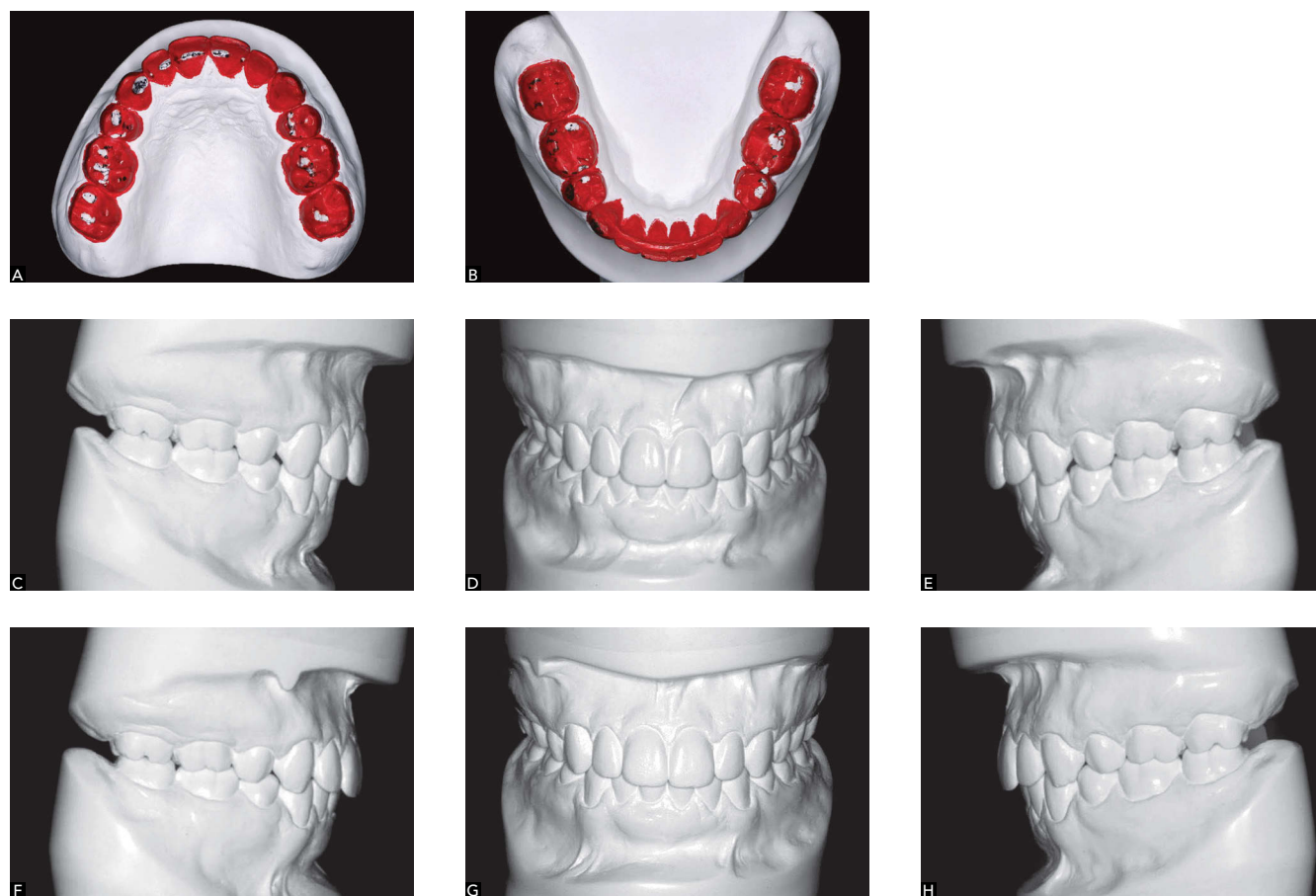


**Figure 5** - A, B) An occlusal analysis is done initially on CR mounted models before the occlusal equilibration is carried out on the patient. C-H) Comparison of pre (top row) (C, D, E) post (bottom row) occlusal equilibration. F, G, H).

us to forecast the normal growth of the patient and the anticipated influences of treatment, to establish the individual objectives we want to achieve for that patient and establish the most ideal treatment mechanics used to reach these goals.<sup>12</sup>

**Do you believe in early treatment? In your opinion, what is the best time to initiate treatment in crowded patients? Roberto Lima**

Early treatment can offer many benefits to young patients when indicated. In my opinion, the best time to initiate treatment in crowded patients is after the permanent central incisors and the first permanent molars have

erupted. If possible, the permanent lateral incisors should also present radiographically at least some of their roots developed. Rapid maxillary expanders and mandibular Schwarz appliances are routinely used in our practice to improve crowding during early treatment. Special attention is paid to the attached gingiva, especially on the facial of the mandibular incisors. In certain cases where crowding is severe, serial extractions may be considered, or if orthopaedic expansion is carried out, patients and parents are made aware that bicuspid extractions may still be necessary during the second phase of treatment, even in the absence of crowding, to achieve an ideal functional occlusion (usually in high angle cases).

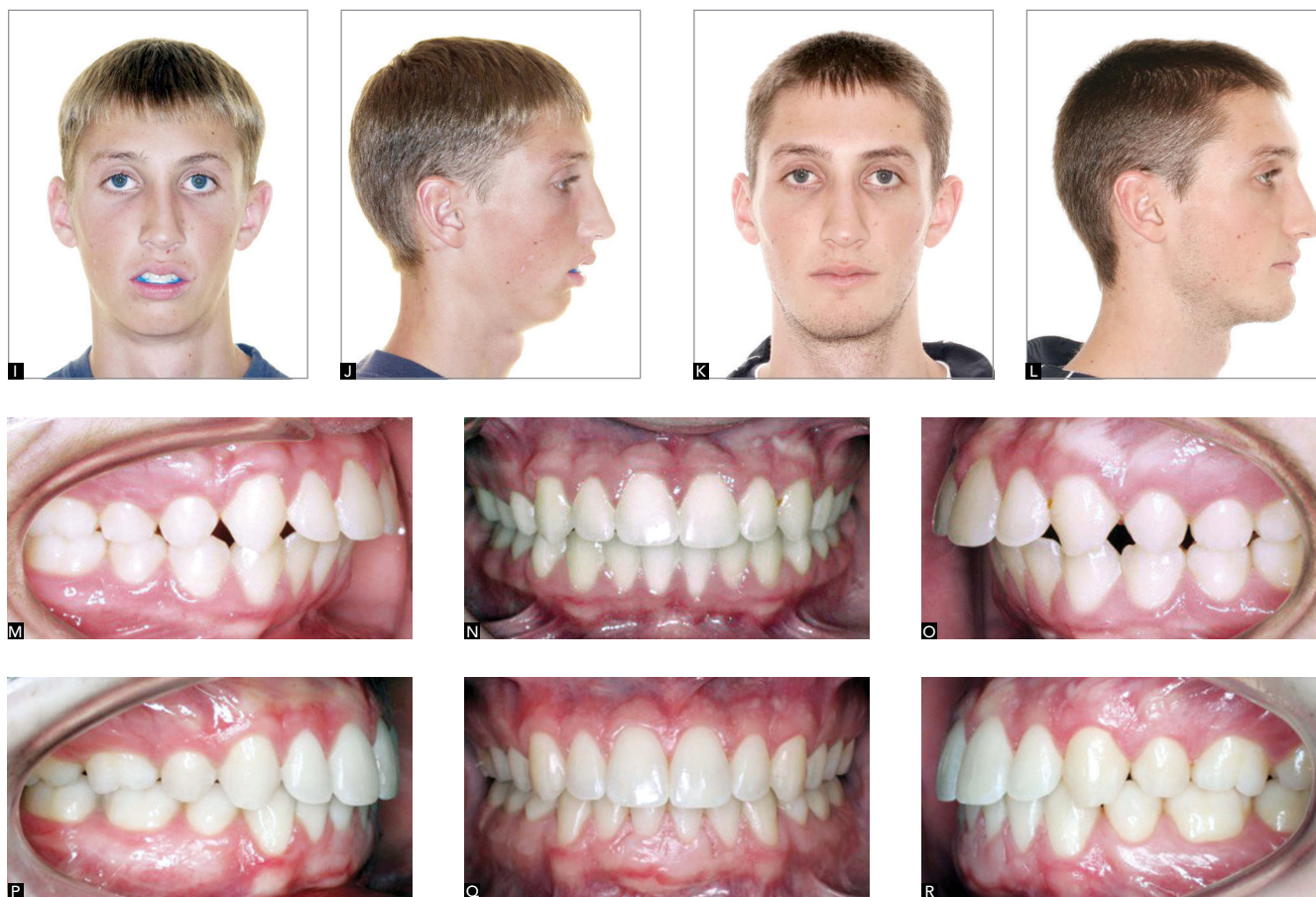


**Figure 5 (II)** - Pre-treatment (I, J; M, N, O) and post-treatment facial photographs (K, L; P, Q, R) of the same patient shown in Figures 5A to 5H. The patient had completed comprehensive treatment at a different orthodontic office one month before the pre-treatment photographs were taken. The patient and his family were unhappy with the results and had been referred to us by their general dentist for a second opinion. Four family members were in the dental field and felt that the final occlusion was not ideal. The patient presented with a severe Class II skeletal discrepancy which had been initially misdiagnosed and orthodontically treated only for several years. After gathering the proper diagnostic records, it was decided that a connective tissue grafting procedure to reinforce the attached gingiva on the facial of the mandibular incisors, extractions of the second bicuspid to reduce the proclination of the incisors, and orthognathic surgery would be necessary to attain the most ideal functional occlusion.

Orthopaedic expansion during early treatment has always been considered an important tool in attaining aesthetically pleasing smiles in our practice. It has become even more important in our early treatment planning with the current increase in awareness of problems associated with sleep apnea.<sup>13</sup>

**What is your protocol for finishing your cases? Do you use positioners?** Roberto Lima

A Centric Relation Tooth Positioner is another important tool that is used in our practice during the retention phase to produce results that are consistently optimal and excellent. The CR mounted models gathered for the fabrication of the tooth positioner also aid us in making a final evaluation of the positions of each tooth and the degree of any remaining CO-CR discrepancy. It is important to clarify that tooth positioners should not be used to correct grotesque imperfections or obvious occlusal or skeletal discrepancies that may be due to inadequate diagnosis or ill treatment mechanics. They are used in our practice during the “settling” stage to improve minor discrepancies associated with rotations, open contacts, minor marginal ridge discrepancies, and occlusal interferences that may not be readily noticed during a clinical evaluation.

When it is decided that the patient is ready to be debonded, a thorough explanation of each retainer, including the tooth positioner, is given to the patient and the accompanying parent. The reason and importance of each retainer is explained in detail using samples of each appliance and it is confirmed that the patient will be committed to wear all retainers as indicated.

Over the past 18 years of using CR tooth positioners, I have found very few patients who refuse to wear one. I strongly believe that excellent communication can yield patient's trust and desirable cooperation leading to ideal treatment results.

An obvious difference in the quality of the finished results can be observed between the time of debond and after 8 weeks of wearing a CR tooth positioner.

**What is your protocol for retention? What type of retainer do you use in the lower arch? Do you believe in long-term retention?**

Roberto Lima

As mentioned before, our retention protocol after comprehensive treatment includes a CR tooth positioner delivered at the debond appointment (worn full-time for 4 days, and 4 hours plus nights for 7 weeks), followed by a maxillary clear retainer and a mandibular spring aligner. The upper and lower removable retainers are worn every night as soon as they are delivered. If TMD and/or parafunctional habits were present at the start of treatment, a CR splint becomes the maxillary removable retainer of choice.

After approximately 24 months of supervised retention, patients are “graduated” from our practice, but we let them and the referring dentists know that they can contact us if problems would arise in the future. We used to tell patients at this point of their retention phase that they could start wearing the removable retainers 1-2 nights per week, but we found out that some would stop wearing them all together. So instead, we now recommend wearing the retainers every night for an indefinite period of time.

If implants are necessary to replace missing teeth in a growing patient, or additional skeletal growth is being monitored, such as in Class III cases, we will continue to periodically evaluate these patients until growth has ceased (18-20 years old in females and 21-22 years old in males).

**Do you employ the indirect bonding technique in all your patients? What are the advantages of this technique?**

Roberto Lima

I have been using the Indirect Bonding Technique for over 24 years. It is utilized on almost every single patient in our practice. Few exceptions include some very limited early treatment cases. This technique offers a method that can be used to place brackets with repeated accuracy, minimizing the amount of bracket repositioning necessary to finish treatment in a minimal amount of time, while meeting all the goals of a functional occlusion.

No amount of detailing of an archwire can compensate for a series of poorly placed brackets. Unlike an intra-oral approach, patient's models can be viewed in all three dimensions to facilitate accurate bracket placement. Bracket placement should be pre-planned just like other aspects of the treatment plan. Indirect bonding also allows the doctor's time to be used efficiently and effectively in the clinic.

While many orthodontists may consider the Indirect Bonding Technique to be too time consuming, involving extra steps gathering impressions of the teeth and creating transfer trays in the laboratory, I believe that, at the end, this extra time spent is justified by the time saved when finishing treatments on time or ahead

of time due to better bracket placement right from the start. Having done thousands of cases indirectly has allowed me the ability to recognize ill bracket positions more easily and to improve these early in treatment and therefore, avoid round tripping of the teeth.

Another area that may keep orthodontists away from using the Indirect Bonding Technique as well as mounting their cases, involves organizational skills in the clinic and throughout their practice. I believe in systems to keep any type of business flowing smoothly and to consistently obtain ideal results. A good source that can be used as reference in creating systems in any small business is the popular book by Michael Gerber, "E-Myth". In this book, he explains how one of the keys to a successful business is creating a business development cycle "Innovation, Quantification, and Orchestration." Implementation of systems and keeping things well organized and consistent is also important in any orthodontic practice. For example, in our office, we strive to keep every unit and drawer stocked the exact same way to increase efficiency, and we try to schedule most indirect bondings (start and debond appointments) with one or two technicians that are highly specialized in performing these procedures, even though the rest of the staff is also trained to perform any of them whenever necessary. This scheduling system plan allows us the ability to streamline and solve inaccuracies or failures more easily.

I would like to thank you for the invitation to be interviewed. Brazil is very dear to me, and I have become very fond of this country and its people over the years, especially after having had the opportunity to lecture in several of its beautiful cities in 2002.

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# Transverse effect of Haas and Hyrax appliances on the upper dental arch in patients with unilateral complete cleft lip and palate: A comparative study

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**Objective:** The aim of the present study was to evaluate the transverse effect of rapid maxillary expansion in patients with unilateral complete cleft lip and palate while comparing the Haas and Hyrax appliances.

**Methods:** The sample consisted of 48 patients divided into two groups: Group I – 25 patients treated with modified Haas appliance (mean age: 10 years 8 months); and Group II – 23 patients treated with Hyrax appliance (mean age: 10 years 6 months). Casts were taken during pre-expansion and after removal of the appliance at the end of the retention period. The models were scanned with the aid of the 3 Shape R700 3D scanner. Initial and final transverse distances were measured at cusp tips and cervical-palatal points of maxillary teeth by using the Ortho Analyzer™ 3D software.

**Results:** The mean expansion obtained between cusp tips and cervical-palatal points for inter-canine width was 4.80 mm and 4.35 mm with the Haas appliance and 5.91 mm and 5.91 mm with the Hyrax appliance. As for first premolars or first deciduous molars, the values obtained were 6.46 mm and 5.90 mm in the Haas group and 7.11 mm and 6.65 mm in the Hyrax group. With regard to first molars, values were 6.11 mm and 5.24 mm in the Haas group and 7.55 mm and 6.31 mm in the Hyrax group.

**Conclusion:** Rapid maxillary expansion significantly increased the transverse dimensions of the upper dental arch in patients with cleft palate, with no significant differences between the Haas and Hyrax expanders.

**Keywords:** Palatine expansion technique. Cleft palate. Dental arch.

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

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## INTRODUCTION

Unilateral complete cleft lip and palate simultaneously involves the primary and secondary palate and accounts for 30% of all clefts. This condition requires more extensive treatment, as the cleft divides the maxilla and the alveolar arch into two completely distinct segments.<sup>1</sup> Treatment initially involves primary functional and esthetic surgeries for the closing of the lip and palate, which have a long-term impact on mid face growth.<sup>2,3</sup> The patient is then followed up throughout the growth period until entering the orthodontic phase (end of the deciduous dentition phase).<sup>4</sup>

Primary surgeries of the lip and palate usually potentiate reductions in the transverse and sagittal dimensions of the upper arch as a consequence of the restricted growth of the mid face and the approximation of the initially separated maxillary segments.<sup>3</sup> These sagittal and transverse deficiencies of the upper alveolar arch is expressed already at the mixed dentition phase and tend to become aggravated in adolescence.<sup>5</sup> Thus, the task of orthodontists is to counteract the harmful effects of the altered facial growth also characterized by posterior and anterior cross bite — often found in patients with cleft lip and palate.<sup>6</sup>

Besides other occlusion issues,<sup>7</sup> posterior cross bite is the most common malocclusion in these patients, involving a single tooth or the entire dental arch, showing a tendency toward exacerbation from the mixed to the permanent dentition. Interceptive orthodontic interventions should be performed during the mixed dentition phase for correction of the compromised transverse dimension.<sup>8</sup> Moreover, the expansion of the upper arch also plays an important role in preparing the arch and cleft region for the secondary alveolar bone graft, which is performed at the end of the mixed dentition prior to the eruption of the permanent canine adjacent to the cleft region.<sup>4</sup>

Rapid maxillary expansion performed by means of a Haas or Hyrax appliance is the most common method employed at the Hospital for Rehabilitation of Craniofacial Anomalies (USP, Brazil) to increase the width of the maxilla. The main difference between the two appliances is the type of anchorage: tooth-supported with the Hyrax appliance and tooth-mucosa-supported with the Haas appliance.

The active expansion phase in patients with unilateral complete cleft lip and palate promotes distancing

of the maxillary segments and widening of the cleft.<sup>8</sup> Expansion in these patients is not followed by bone formation at the median palatine suture, as it occurs in patients without cleft palate,<sup>9</sup> because the distancing of the maxillary halves occurs in the region of the cleft. Thus, retention should remain after the appliance is removed and until bone graft is performed. Expansion in such patients involves similar restrictions to those found in patients without cleft palate, as the other maxillary sutures offer considerable resistance to widening, requiring orthopedic appliances.

Motivated by the interest in evaluating the results of the expansion philosophy of the team at the Hospital for Rehabilitation of Craniofacial Anomalies/USP, the aim of the present prospective study was to assess alterations in the transverse dimension of the upper dental arch in patients with unilateral complete cleft lip and palate who have undergone rapid maxillary expansion, comparing the results achieved with the Haas and Hyrax appliances with the aid of digital models.

## MATERIAL AND METHODS

This study was approved by the Hospital for Rehabilitation of Craniofacial Anomalies/USP Institutional Review Board (protocol 255/2010-SVAPEPE-CEP).

The sample consisted of 48 patients enrolled in the orthodontic sector of the hospital. All patients had unilateral complete cleft lip and palate, had undergone primary surgeries at an early age and were in the mixed dentition phase, exhibiting maxillary atresia with an indication for rapid maxillary expansion.

The patients were randomly divided into two groups. Group I comprised 25 patients treated with the modified Haas appliance (Fig 1A), with bands on the permanent molars and orthodontic clip bonded to the deciduous molars (16 males and 9 females; mean age: 10 years 8 months; age range: 8 years to 19 years and 2 months). Group II comprised 23 patients treated with the Hyrax appliance (Fig 1B) (13 males and 10 females; mean age: 10 years 6 months; age range: 8 years and 2 months to 18 years and 1 month). All patients underwent the same activation protocol. The expander was activated for seven days with 2/4 turns in the morning and 2/4 turns in the evening. Whenever necessary, further activation was performed until overcorrection was reached (palatine cusps of the upper molars occluding the vestibular

cusps of the lower molars). Hooks for a facial mask were welded to the inverse traction of the maxilla for patients that also had sagittal discrepancy with good prognosis for orthopedic treatment.

After achieving overcorrection, the screw was stabilized with acrylic resin. The expander was maintained passive with a retention protocol for six months, after which the expander was removed and a fixed retainer was installed.

Dental cast of the maxillary arch were obtained at two different times: immediately before banding for the expander ( $T_1$ ), and after the six-month period of retention immediately following the removal of the expander ( $T_2$ ). The impressions were made with alginate and filled with Paris plaster. The dental casts were then scanned by a 3Shape R700 3D scanner (3Shape A/S, Copenhagen, Denmark), which reproduces a three-dimensional digital image based on laser beams scans projected over the plaster models in different directions. The Ortho Analyzer™ 3D program was used to obtain the three-dimensional image of the scanned models, allowing frontal, lateral, posterior and occlusal visualization. The reference points were marked on the model in the occlusal view for the calculation of the distances between teeth. Figure 2 illustrates the measurements made on the digital models of the upper dental arches.

Analyses were performed by a single examiner. Sixty percent of the sample was analyzed a second time after a seven-day interval in order to determine the measurements reliability using the intraclass correlation coefficient (ICC) for which the following scores were used: 0.80 to 1.00 = excellent agreement; 0.60 to 0.80 = substantial; 0.40 to 0.60 = moderate; 0.20 to 0.40 = fair; 0 to 0.20 = discreet; and -1 to 0 = poor.

Mean, standard deviation (SD), maximum and minimum values were calculated. The paired Student's t-test was employed to determine statistically significant differences between the initial and final measurements of each group. The independent t-test was used for inter-group comparison. The level of significance was set at 5% ( $p < 0.05$ ).

## RESULTS

Tables 1 to 4 display the results of the measurement reliability and transverse distances measured on the models.

## DISCUSSION

Cleft lip and palate occurs in the mid face and causes structural problems in the alveolar bone and maxilla. The urgent relationship with the malocclusion is demonstrated by the anatomic rupture that compromises the alveolar ridge as well as dental problems, such as

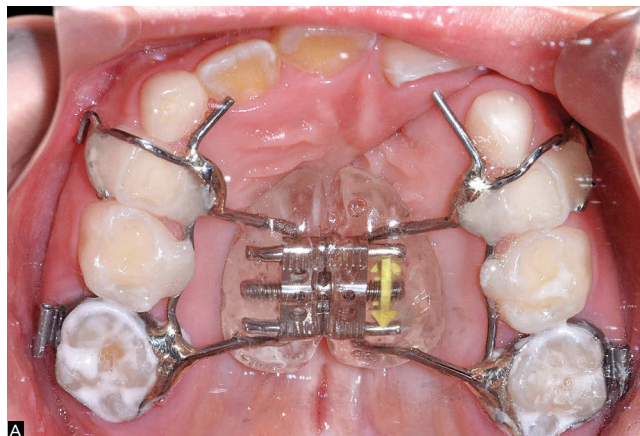


**Figure 1** - Occlusal photographs of two patients from the sample illustrating both expanders: Modified Haas (A) and Hyrax (B)

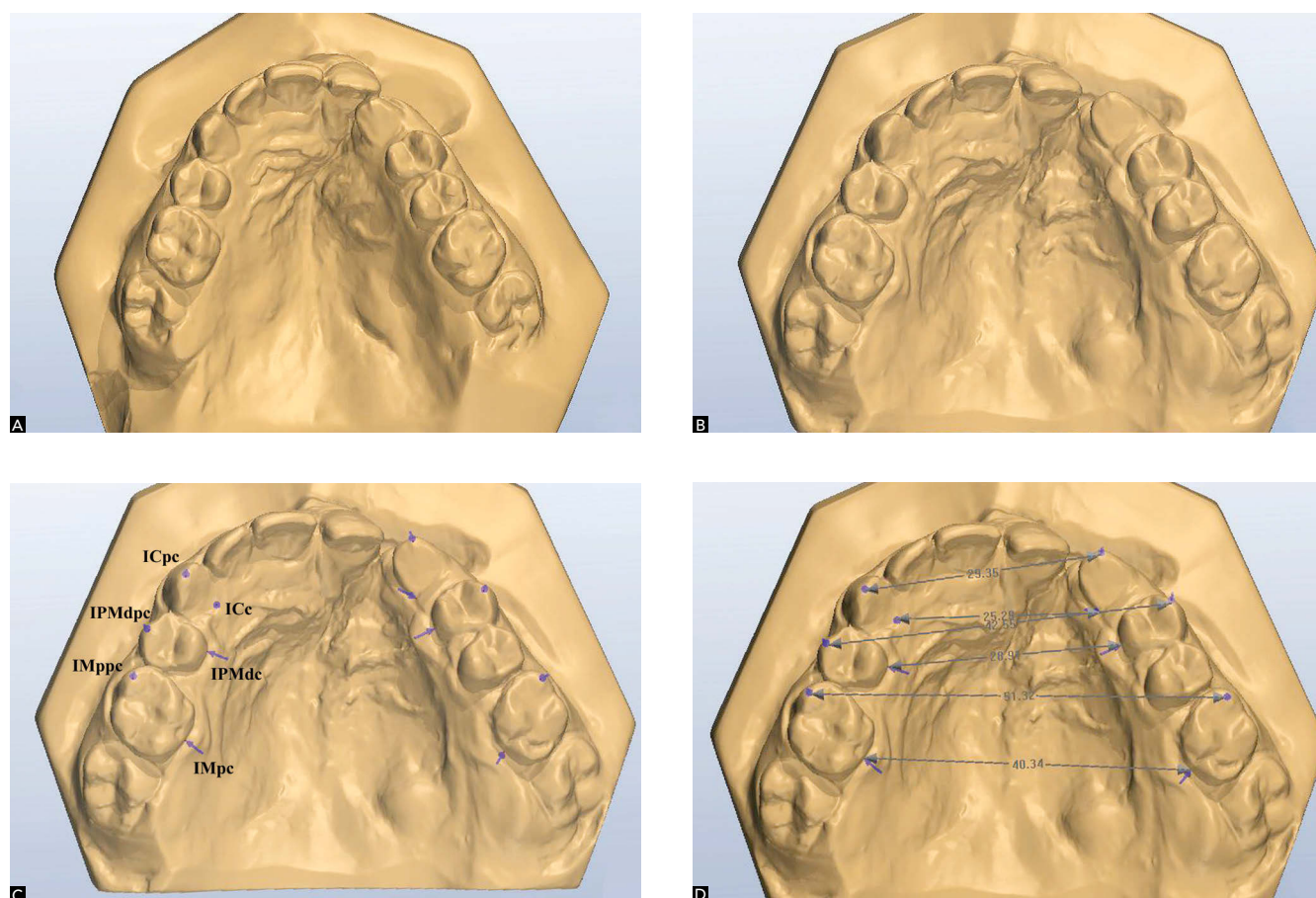


**Figure 2** - Initial and final digital models showing the results of rapid maxillary expansion (A and B); reference points (C) and measurements made (D) on post-expansion models

agenesis and malpositioning, as well as sagittal and transverse maxillary deficiencies.<sup>10</sup> The treatment protocol adopted by the Hospital for Rehabilitation of Craniofacial Anomalies/USP for patients with unilateral complete cleft lip and palate emphasizes early surgical procedures (cheiloplasty and palatoplasty), with no orthopedic intervention in the preoperative or immediate postoperative periods. As a general rule, orthodontic treatment is initiated at the onset of the mixed dentition phase. Two reasons justify the lack of orthodontic intervention in the deciduous dentition phase: the instability of the early correction of cross bites, which leads to an excessively long treatment and retention time; and the fact that alterations in the shape of the dental arch and the occlusion are exacerbated in the mixed dentition phase.<sup>11</sup>

Expansion is the first step of orthodontic treatment (pre-alveolar bone graft). It aims at reestablishing the transverse dimensions of the atresic maxilla. The maxillary expander designed by Haas is the main appliance used for lateral repositioning of the collapsed maxillary processes<sup>6</sup> and follows the same activation protocol used for patients without cleft palate. In this phase, the inverse traction of the maxilla may be associated with the post-expansion period to revert cases of negative sagittal discrepancy, expressed by anterior crossbite.<sup>12</sup> The Hyrax appliance is also commonly used for maxillary expansion. The main difference between the two expanders is the acrylic support on the palate in the Haas appliance. However, both expanders are effective in increasing the transverse dimension of the maxilla. The choice of one over the other is based on the shape

**Table 1** - Error of the method (Intraclass Correlation Coefficient).

| Measure | ICC (Haas) |       | ICC (Hyrax) |       |
|---------|------------|-------|-------------|-------|
|         | Initial    | Final | Initial     | Final |
| ICpc    | 0.99       | 0.82  | 1.00        | 0.99  |
| ICc     | 0.97       | 0.99  | 0.99        | 1.00  |
| IPMdpc  | 0.91       | 1.00  | 0.99        | 1.00  |
| IPMdc   | 0.99       | 0.99  | 1.00        | 1.00  |
| IMppc   | 0.99       | 0.98  | 0.96        | 0.99  |
| IMpc    | 1.00       | 0.99  | 1.00        | 0.99  |

**Table 2** - Transverse distances measured on initial and final digital models and mean amount of expansion (Dif.) in millimeters for patients using the modified Haas expander.

| Measure | Initial model    | Final model      | Dif. | p       |
|---------|------------------|------------------|------|---------|
|         | Mean $\pm$ S.D.  | Mean $\pm$ S.D.  |      |         |
| ICpc    | 26.81 $\pm$ 3.13 | 31.60 $\pm$ 3.35 | 4.79 | < 0.01* |
| ICc     | 21.15 $\pm$ 3.39 | 25.50 $\pm$ 3.76 | 4.35 | < 0.01* |
| IPMdpc  | 35.39 $\pm$ 3.67 | 41.85 $\pm$ 4.22 | 6.46 | < 0.01* |
| IPMdc   | 24.25 $\pm$ 3.03 | 30.15 $\pm$ 3.36 | 5.9  | < 0.01* |
| IMppc   | 49.20 $\pm$ 3.91 | 55.31 $\pm$ 3.28 | 6.11 | < 0.01* |
| IMpc    | 35.29 $\pm$ 2.84 | 40.54 $\pm$ 3.24 | 5.24 | < 0.01* |

\* statistically significant difference (p &lt; 0.05)

**Table 3** - Transverse distances measured on initial and final digital models and mean amount of expansion (Dif.) in millimeters for patients using the Hyrax expander.

| Measure | Initial model    | Final model      | Dif. | p       |
|---------|------------------|------------------|------|---------|
|         | Mean $\pm$ S.D.  | Mean $\pm$ S.D.  |      |         |
| ICpc    | 24.63 $\pm$ 3.98 | 30.54 $\pm$ 2.95 | 5.91 | < 0.01* |
| ICc     | 20.37 $\pm$ 2.96 | 26.28 $\pm$ 3.91 | 5.91 | < 0.01* |
| IPMdpc  | 33.10 $\pm$ 3.71 | 40.21 $\pm$ 3.96 | 7.12 | < 0.01* |
| IPMdc   | 22.72 $\pm$ 3.59 | 29.37 $\pm$ 3.50 | 6.65 | < 0.01* |
| IMppc   | 44.68 $\pm$ 4.26 | 52.23 $\pm$ 3.73 | 7.55 | < 0.01* |
| IMpc    | 31.32 $\pm$ 3.90 | 37.63 $\pm$ 3.79 | 6.31 | < 0.01* |

\* statistically significant difference (p &lt; 0.05)

**Table 4** - Comparison of modified Haas and Hyrax appliances groups regarding mean increase in transverse dimensions of the maxilla following rapid maxillary expansion.

| Measure | Group Haas (n) | Group Hyrax (n) | Difference (mm) | p       |
|---------|----------------|-----------------|-----------------|---------|
| ICpc    | 4.80 (18)      | 5.91 (18)       | 1.11            | 0.16 ns |
| ICc     | 4.35 (11)      | 5.91 (16)       | 1.56            | 0.06 ns |
| IPMdpc  | 6.46 (19)      | 7.11 (16)       | 0.65            | 0.48 ns |
| IPMdc   | 5.90 (19)      | 6.65 (16)       | 0.75            | 0.29 ns |
| IMppc   | 6.11 (24)      | 7.55 (22)       | 1.44            | 0.02*   |
| IMpc    | 5.24 (24)      | 6.31 (21)       | 1.07            | 0.08 ns |

ns = non-significant.

\* statistically significant difference (p &lt; 0.05).

of the patient's palate. Whenever the transverse width and depth allow, the Haas expander is the appliance of choice due to the anchorage provided by its acrylic portion. In the present study, the modified Haas expander was used, which differs from the original by the presence of two orthodontic bands instead of four, and by bonded orthodontic clips on the deciduous molars.

Following the tendency of using digital records in Orthodontics,<sup>13</sup> the evaluation of the transverse effect of the Haas and Hyrax expanders was performed with digital models, which offer advantages in terms of storage, retrieval, durability, diagnostic versatility and transmitting information.<sup>14</sup> Moreover, studies comparing digital and conventional models report considerable accuracy and reproducibility in the measurements of tooth width, overjet and overbite.<sup>15</sup> The ICC of the measurements obtained from the digital models by a single examiner on two different occasions demonstrate the reliability of the method (Table 1).

Both appliances were capable of restoring the adequate upper arch morphology and correcting the posterior cross bite (Figs 1 and 2). The results demonstrate significant increase (p < 0.0001) in all transverse dimensions measured (Tables 2 and 3), which is in agreement with findings reported in the literature.<sup>16</sup>

The increases in the inter-molar, inter-premolar or inter-deciduous molar and inter-canine widths were statistically significant in both groups. The group treated with the Haas expander had an increase in inter-molar distance of 6.11 mm on the tips of the mesiovestibular cusps, 5.24 mm on the palatine-cervical portion of the molars, and an increase in the inter-canine distance of 4.79 mm when measured on the cusps and 4.35 mm when measured on the palatine-cervical portion (Table 2). These values are similar to those reported by previous studies.<sup>17,19</sup> In a study involving digital models of 32 children without cleft palate and with unilateral or bilateral cross bite (16 children treated with the Haas expander and 16 treated with the Hyrax expander), the Haas group had an increase in inter-molar distance of 6.33 mm on the tips of the mesiovestibular cusps and 6.04 mm on the central sulcus of the first molars; an increase in the inter-canine distance of 2.27 mm when measured on the cusps and 4.74 mm when measured on the cervical portion.<sup>20</sup>

In the present study, the patients treated with the Hyrax expander had an increase in inter-molar distance of 7.55 mm on the tips of the mesiovestibular cusps and 6.31 mm in the palatine-cervical portion; an increase in the inter-canine distance of 5.91 mm when measured on the cusps or on the palatine-cervical portion (Table 3). These results are similar to findings reported in the literature for patients in the mixed dentition phase treated with the Hyrax expander.<sup>19,21,23</sup> However, another study reports larger increases (9.97 mm in inter-molar distance on the tips of the mesiopalatine cusps and 9.51 mm in the in the mesial portion of the central sulcus of the and 7.93 mm in the inter-canine distance when measured on the cusps and 6.29 mm when measured on the cervical portion).<sup>20</sup>

No statistically significant differences were found between groups in the comparison of the inter-molar and inter-canine distances obtained with the Haas or Hyrax appliances, except for the inter-molar distance measured on the tips of the cusps, which was greater in the Hyrax group (Table 4). This was likely due to the greater tooth tipping caused by this appliance.

Discrepant results are reported in the literature, with some studies reporting a greater increase in inter-molar and inter-canine distances using the Hyrax expander<sup>20</sup> and others reporting a greater tendency of vestibular tipping of molars using the Haas expander.<sup>16</sup> Both appliances generally demonstrate similar behavior regarding the expansion of the dentoalveolar region of the maxilla.<sup>24</sup> However, the Haas expander may cause greater vestibular tipping of the anchoring teeth (3.5° for the first molar) in comparison to the Hyrax expander (1.6°), although this is not a clinically relevant difference.<sup>24</sup>

## CONCLUSIONS

- Rapid maxillary expansion using the modified Haas and Hyrax expanders proved efficient in increasing the transverse dimensions of the upper dental arch in patients with unilateral complete cleft lip and palate.

- No significant differences between appliances were found regarding the transverse effects produced by the modified Haas and Hyrax expanders in the present study.

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# The influence of orthodontic fixed appliances on the oral microbiota: A systematic review

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**Objective:** To investigate whether there is scientific evidence to support the hypothesis that the presence of orthodontic fixed appliances influences the oral microbiota.

**Methods:** The search for articles was conducted in PubMed; ISI Web of Knowledge and Ovid databases, including articles published in English until May 17<sup>th</sup>, 2012. They should report human observational studies presenting the following keywords: “fixed orthodontic appliance” AND “microbiological colonization”; OR “periodontal pathogens”; OR “*Streptococcus*”; OR “*Lactobacillus*”; OR “*Candida*”; OR “*Tannerella forsythia*”; OR “*Treponema denticola*”; OR “*Fusobacterium nucleatum*”; OR “*Actinomyces actinomycetemcomitans*”; OR “*Prevotella intermedia*”, OR “*Prevotella nigrescens*”; OR “*Porphyromonas gingivalis*”. Articles were previously selected by title and abstract. Articles that met the inclusion criteria were analyzed and classified as having low, moderate or high methodology quality. A new detailed checklist for quality assessment was developed based on the information required for applicable data extraction for reviews. The study design, sample, follow-up period, collection and microbial analysis methods, statistical treatment, results and discussion were assessed.

**Results:** The initial search retrieved 305 articles of which 33 articles were selected by title and abstract. After full-text reading, 8 articles met the inclusion criteria, out of which 4 articles were classified as having low and 4 as moderate methodological quality. The moderate methodological quality studies were included in the systematic review.

**Conclusions:** The literature revealed moderate evidence that the presence of fixed appliances influences the quantity and quality of oral microbiota.

**Keywords:** Orthodontic appliances. Periodontics. Attachment sites. Microbiological. Microbiological analysis.

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## INTRODUCTION

Scientific publications have demonstrated that the presence of fixed appliances in the oral cavity of orthodontic patients could alter the nature of dental plaque.<sup>1</sup> The structure, metabolism and composition of dental plaque would change, leading to an increase in microbial population, especially *Streptococcus* and *Lactobacillus*.<sup>1,7</sup>

Some authors have observed that fixed appliances might hamper effective oral hygiene and cause high cariogenic challenge.<sup>8,11</sup> Furthermore, based on the difficulty of maintaining oral hygiene, the subgingival microbiota may also be influenced by orthodontic appliances,<sup>13,14</sup> since orthodontic accessories would favor bacterial plaque retention. These variables would possibly lead to pathogenic bacteria colonization, which are responsible for gingival inflammation, periodontal support destruction<sup>13,14</sup> and changes in enamel surface.<sup>7,8,11,12</sup>

Published literature has shown that conditions favoring microbial colonization and establishment of *Streptococcus spp*, *Lactobacillus spp*, fungi and periodontal pathogens increase microbial population growth and plaque accumulation. Therefore, the following question arises: What is the real influence of orthodontic fixed appliances over balance of oral microbiota in orthodontic patients?<sup>7,10,13-17</sup>

Thus, the aim of this systematic review was to evaluate whether there is scientific evidence to support the hypothesis that the presence of orthodontic fixed appliances alters the composition of oral microbiota and, as a consequence, favors the development of caries and periodontal disease.

## MATERIAL AND METHODS

The search for articles was conducted in PubMed; ISI Web of Knowledge and Ovid databases. Articles published in English from 1945 to May 2012 were included. The following keywords were used in the preliminary search: “fixed orthodontic appliance” AND “microbiological colonization”; OR “periodontal pathogens”; OR “*Streptococcus*”; OR “*Lactobacillus*”; OR “*Candida*”; OR “*Tannerella forsythia*”; OR “*Treponema denticola*”; OR “*Fusobacterium nucleatum*”; OR “*Actinomyces actinomycetemcomitans*”; OR “*Prevotella intermedia*”, OR “*Prevotella nigrescens*”; OR “*Porphyromonas gingivalis*”. As for the Ovid database, the keyword “periodontal pathogens” was replaced by “periodontal disease”, since

the former was not indexed. The search strategy and the flow of information through the different phases of the systematic review were established according to the PRISMA statement for systematic reviews and metaanalysis.<sup>18</sup> The articles were selected, evaluated and classified by two independent readers. The results of both readers were compared and eventual differences were solved by common accord.

Initially, all articles were selected by title and abstract. Should articles repeat in different databases, they were considered only once. The publications selected were essentially observational clinical studies conducted in humans. They were required to describe the microbial colonization in orthodontic fixed appliances in individuals submitted to corrective orthodontic treatment. Afterwards, inclusion and exclusion criteria were applied. The following inclusion criteria were applied: observational clinical studies in humans; presence of orthodontic fixed appliances placed onto the buccal tooth surface; standardization and training in oral hygiene; microbiological analysis of collected material. Conversely, the exclusion criteria were: absence of baseline investigation before appliances were placed; inclusion of patients with systemic diseases or under any condition that could influence oral microbiota or periodontal support tissues; antibiotic therapy three months before and during the study; use of mouth rinse during investigation; no standardization and training in oral hygiene; fixed or removable orthodontic appliances on the lingual dental surface. The articles that did not fulfil all the inclusion criteria in the abstract section, but did not meet any exclusion criteria were not excluded at this stage.

Subsequently, full text articles were read and those that met the inclusion and exclusion criteria were carefully analyzed and qualified according to their methodological aspects, as described in Table 1. A new detailed checklist for quality assessment was developed specifically for this review, based on the information required for data extraction applicable for reviews.<sup>19</sup> The selected articles were finally classified according to the total score after qualification. Their methodological quality was classified as high (score 9 and 10), moderate (score from 6 to 8.9) or low (score from 0 to 5.9). Those classified as low were excluded. A hand search was performed to complement the previous searches, by which the references of the selected articles were analyzed.

Table 1 - Methodological quality score.

| Score protocol                                                                                                                                                                             | Maximum score (10 points) |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| 1. Study design: description of the study design                                                                                                                                           | 0.2                       |
| 2. Participants                                                                                                                                                                            | 1.2                       |
| Sample standards: participant's inclusion and exclusion criteria.                                                                                                                          | 0.2                       |
| Sample characterization: number and characteristic of participants.                                                                                                                        | 0.2                       |
| Calculation of sample size                                                                                                                                                                 | 0.6                       |
| Ethics: evidence of ethical factors                                                                                                                                                        | 0.2                       |
| 3. Study follow-up period                                                                                                                                                                  | 2.0                       |
| 3 a 5 months                                                                                                                                                                               | 0.5                       |
| ≥ 6 months                                                                                                                                                                                 | 1.5                       |
| Month collections                                                                                                                                                                          | 0.5                       |
| 4. Collection methods                                                                                                                                                                      | 3.0                       |
| Control of factors influencing collection: collection under dry conditions, removal of supragingival plaque and debris                                                                     | -                         |
| 5. Microbial analysis methods                                                                                                                                                              | 3.0                       |
| Culture methods                                                                                                                                                                            | 1.0                       |
| Molecular biology                                                                                                                                                                          | 1.5                       |
| Mean standard deviation                                                                                                                                                                    | 0.5                       |
| 6. Statistical analysis: adequate (indication of the test applied and significance level)                                                                                                  | 0.2                       |
| 7. Results: adequate presentation of results (presentation of all proposed results; comparison between results considering time and microorganism; participant dropout with justification) | 0.2                       |
| 8. Discussion: consideration and possible explanation for the findings presented; comparison with previous published results                                                               | 0.2                       |

## RESULTS

A total of 305 titles and abstracts retrieved from the selected databases were screened. There were 136 from PubMed, 104 from Ovid and 65 from ISI Web of Knowledge. However, the duplicates were considered only once, thus totaling 250 articles.

Initially, the titles and abstracts not connected with the topic were excluded. Afterwards, the articles were selected according to the inclusion and exclusion criteria, thus totaling 33 articles. At this stage, all studies that presented at least one inclusion criterion in the abstract section, but presented none of the exclusion criteria, were kept. If any pre-selected article was inaccessible or not written in English, a direct request was made to the authors. After two months waiting for contact, 10 studies were excluded. Thus, 23 full texts were analyzed considering all selection criteria. The absence of any inclusion criteria at this stage determined the exclusion of 16 studies.

A hand search was performed with the references of the 7 remaining articles in order to screen additional publications not retrieved by the databases used. Thus, 23 new titles were retrieved. After reading the abstract,

12 articles were excluded. Subsequently, the texts of 11 articles were fully read and 10 other articles were also excluded. Therefore, 1 article obtained by hand search was added to the 7 previously selected articles.

Thus, the 8 selected articles were carefully read and ranked based on the quality assessment previously described, as shown in Table 2. After qualification, 4 articles were considered as having moderate scientific evidence whereas 4 were classified as having low scientific evidence. All articles classified as having low scientific evidence were excluded from this systematic review. Consequently, 4 studies were included (Fig 1). The distribution of articles is detailed in Table 3.

## DISCUSSION

Dental caries and periodontal diseases are recognized as consequences of inadequate oral hygiene during orthodontic treatment.<sup>20</sup> Fixed appliances and rough-surfaced adhesives in the oral cavity create new retentive sites favorable to plaque accumulation and inflammatory response.<sup>20,21</sup>

Although new appliances as well as new bonding techniques and material have been developed, it has

Table 2 - Quality assessment.

| Author/<br>Year                           | Study<br>design | Participants        |                            |                               |        | Study follow-up<br>period |                        |                          | Col-<br>lection<br>methods                   | Microbial analy-<br>sis methods |                   |     | Statistical<br>analysis | Results | Discus-<br>sion | Total<br>points/<br>quality |
|-------------------------------------------|-----------------|---------------------|----------------------------|-------------------------------|--------|---------------------------|------------------------|--------------------------|----------------------------------------------|---------------------------------|-------------------|-----|-------------------------|---------|-----------------|-----------------------------|
|                                           |                 | Sample<br>Standards | Sample<br>Characterization | Calculation<br>of sample size | Ethics | 3-5 month<br>follow-up    | ≥ 6 month<br>follow-up | 1 month<br>interval time | Control of factors<br>influencing collection | Culture methods                 | Molecular biology | SEM |                         |         |                 |                             |
| Sinclair<br>et al, <sup>20</sup> 1987     | 0               | 0.2                 | 0.2                        | 0                             | 0      | 0                         | 1.5                    | 0                        | 3.0                                          | 1.0                             | 0                 | 0   | 0.2                     | 0.2     | 0.2             | 6.5 /<br>Moderate           |
| Paolantonio<br>et al, <sup>23</sup> 1997  | 0               | 0.2                 | 0.2                        | 0                             | 0      | 0                         | 1.5                    | 0                        | 3.0                                          | 1.0                             | 0                 | 0   | 0.2                     | 0.2     | 0.2             | 6.5 /<br>Moderate           |
| Paolantonio<br>et al, <sup>22</sup> 1999  | 0               | 0.2                 | 0.2                        | 0                             | 0      | 1.0                       | 0                      | 0.5                      | 3.0                                          | 1.0                             | 0                 | 0   | 0.2                     | 0.2     | 0.2             | 6.0 /<br>Moderate           |
| Jordan<br>et al, <sup>27</sup> 2002       | 0               | 0.2                 | 0.2                        | 0                             | 0      | 1.0                       | 0                      | 0.5                      | 0                                            | 0                               | 1.5               | 0   | 0                       | 0       | 0.2             | 3.6 /<br>Low                |
| Hagg<br>et al, <sup>5</sup> 2004          | 0.2             | 0.2                 | 0.2                        | 0                             | 0      | 1.0                       | 0                      | 0                        | 0                                            | 1.0                             | 0                 | 0   | 0.2                     | 0.2     | 0.2             | 3.2 /<br>Low                |
| Turkkahraman<br>et al, <sup>11</sup> 2005 | 0               | 0.2                 | 0.2                        | 0                             | 0.2    | 0                         | 0                      | 0.5                      | 0                                            | 1.0                             | 0                 | 0   | 0.2                     | 0.2     | 0.2             | 2.7 /<br>Low                |
| Ristic<br>et al, <sup>21</sup> 2007       | 0.2             | 0.2                 | 0.2                        | 0                             | 0.2    | 0                         | 1.5                    | 0                        | 3.0                                          | 1.0                             | 0                 | 0   | 0.2                     | 0.2     | 0.2             | 6.9 /<br>Moderate           |
| Andrucioli<br>et al, <sup>28</sup> 2012   | 0               | 0.5                 | 0.5                        | 0                             | 0.2    | 0                         | 0                      | 0.5                      | 0                                            | 0                               | 1.5               | 0   | 0.2                     | 0.2     | 0.2             | 3.8 /<br>Low                |

not yet been possible to decrease dental plaque retention.<sup>20,21</sup> Therefore, plaque retention is considered a real problem in Corrective Orthodontics.<sup>21</sup> Difficulties in maintaining oral hygiene around the appliances may result in hyperplastic marginal gingivitis which can advance to periodontitis.<sup>20,22</sup>

There is a consensus that oral microorganisms are the primary etiologic agents of periodontal diseases, and their different species are responsible for the different forms of the disease. Periodontal health is associated with supragingival gram-positive microbiota that consists mainly of diverse species of *Streptococci* and *Actinomyces*. They are also predominant in gingivitis, however, the amount of gram-negative bacteria, such as *Fusobacterium* and *Bacteroides*, increases. On the other hand, in periodontitis, the microflora is dominated by gram-negative facultative anaerobes, with increases spirochetes. The pathogenic potential of these microorganisms is related to their virulence and capacity to act in gingival tissues. Moreover, the virulence of bacteria depends on many factors, especially bacterial serotype and individual host susceptibility.<sup>20,22</sup>

In the retrieved articles, different microbiological studies were developed, revealing different aspects of supragingival plaque and important changes in the composition of subgingival plaque of orthodontic patients.<sup>21</sup> These studies also reported the clinical implications of environmental disturbances caused by fixed appliances, considering the following as determinant factors of periodontal conditions: presence/absence of dental plaque, gingival bleeding index, pocket probing depth and attachment levels in orthodontic patients.<sup>20-23</sup>

Although the articles considered for this review reported that fixed orthodontic appliances influence the oral microbiota, it is relevant to point out that insufficient methodological information was provided.

Only two publications described the study design and the ethical aspects used for conducting the research.<sup>5,21</sup> The diversified results observed can be attributed to the distinct methods applied. The different follow-up periods and collection times, as well as specificity and sensitivity of microbiological analysis were the major factors behind data diversity.<sup>24,25</sup> However, in all the studies included, the biological material was

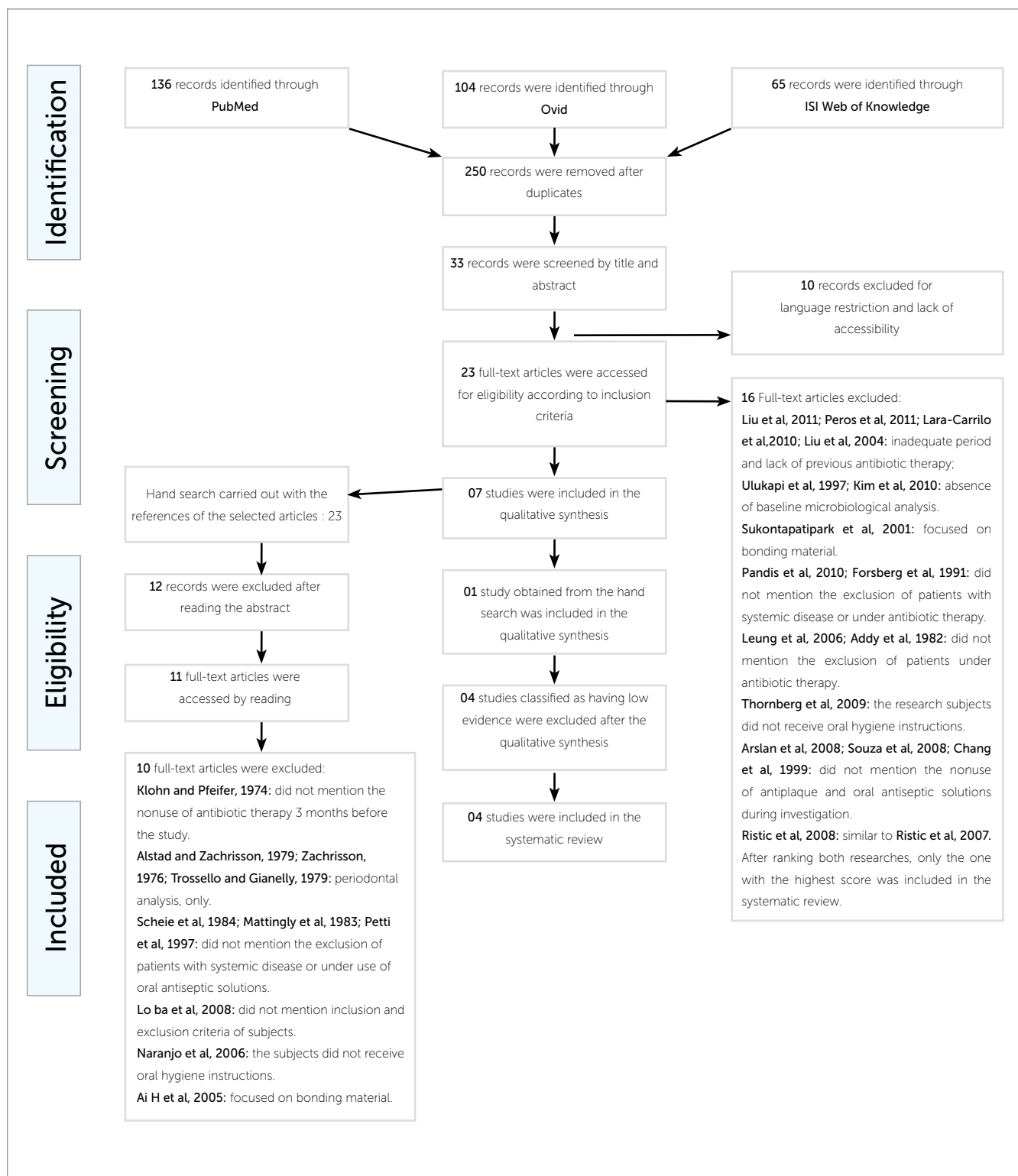


Figure 1 - PRISMA Flow diagram of literature search.

Table 3 - Characteristics of studies included in the review (detailed quality information).

| Author/<br>Year                             | Study<br>design        | Participant                                                                                                                                                                                                      |                                                                                     | Material<br>collection<br>time                                                                                                                                                                                                      | Collection<br>methods                                                                                                                                                                                                         | Microbial<br>analysis<br>methods                 | Statistical<br>analysis                                                                                                                                                                                                                                                     | Conclusion                                                                                                                                                                                                                             |
|---------------------------------------------|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                             |                        | Sample<br>Standards                                                                                                                                                                                              | General<br>sample<br>description                                                    | Total study<br>time/ interval<br>times                                                                                                                                                                                              | Control<br>of factors<br>influencing<br>collection                                                                                                                                                                            | Culture<br>methods/<br>molecular<br>biology/ SEM |                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                        |
| Sinclair<br>et al, <sup>20</sup><br>1987    | Not<br>mentioned.      | No history of<br>orthodontic<br>treatment,<br>systemic disease<br>or use of antibiotic<br>therapy within<br>the preceding<br>6 months; no<br>fluoride rinse<br>or gel was used<br>before or during<br>the study. | 13 subjects, 8<br>males and 5<br>females, aged<br>between 12 and<br>16 years old.   | Collection at<br>baseline and<br>1 year after<br>placement of<br>orthodontic<br>appliance /<br>Material from<br>maxillary and<br>mandibular<br>central incisors,<br>maxillary and<br>mandibular right<br>first permanent<br>molars. | Plaque collected<br>with 0.016" stainless<br>steel orthodontic<br>wire 20 mm in<br>length inserted in<br>the gingival cervixes/<br>Under dry field<br>conditions with<br>cheek retractors,<br>cotton rolls and<br>aspiration. | Culture methods.                                 | Two- way<br>ANOVA for<br>comparison<br>between the<br>sampling<br>periods and<br>Student's- t test<br>for unmatched<br>data.                                                                                                                                                | Increase in the<br>percentage of<br><i>Streptococci</i><br>and decrease in<br>the percentage<br>of Aa in the<br>subgingival plaque;<br>no increase in<br>the percentage<br>of potentially<br>pathogenic<br>Gram-negative<br>organisms. |
| Paolantonio<br>et al, <sup>23</sup><br>1997 | Longitudinal<br>study. | Subjects were<br>not affected by<br>systemic diseases,<br>nor had taken<br>antibiotics during<br>the 3 months<br>preceding each<br>microbiological<br>examination.                                               | 70 subjects, 27<br>males and 43<br>females, aged<br>between 12 and<br>20 years old. | Collection before<br>placement of<br>fixed orthodontic<br>appliance and<br>3 years after/<br>Sampling was<br>performed at<br>mesio-buccal<br>sites of 1 <sup>st</sup> molars<br>and disto-buccal<br>sites of lateral<br>incisors.   | Plaque samples:<br>insertion of 3 sterile<br>paper points at<br>the deepest part<br>of each gingival<br>sulcus/ Removal of<br>supragingival plaque<br>by a sterile curette,<br>gingival surface dried<br>by gentle air flow.  | Culture methods.                                 | Mean % of Aa*<br>in the total<br>anaerobic flora<br>from sampled<br>sites was<br>calculated for<br>each individual;<br>$\chi^2$ analysis to test<br>the statistical<br>significance<br>of differences<br>in the number<br>of Aa* in<br>orthodontic and<br>control subjects. | The presence<br>of orthodontic<br>appliances<br>significantly<br>increases<br>subgingival<br>colonization by Aa<br>among individuals<br>presenting<br>initial healthy<br>periodontium.                                                 |
| Paolantonio<br>et al, <sup>22</sup><br>1999 | Not<br>mentioned.      | No loss of<br>periodontal<br>attachment,<br>no systemic<br>disease,<br>no antibiotics<br>taken during<br>the 3 months<br>before study or<br>during it, and no<br>mouthwash rinse.                                | 24 subjects, 11<br>males and 13<br>females, aged<br>between 18 and<br>22 years old. | Collection at<br>baseline, 4, 8 and<br>12 weeks after<br>bonding/ Material<br>from mesio-buccal<br>sites of the first<br>molars and<br>distobuccal sites<br>of lateral incisors.                                                    | Plaque obtained<br>by insertion of<br>3 sterile paper<br>points at gingival<br>sulcus/ Collected<br>after removal of<br>supragingival plaque<br>with a sterile curette,<br>gingival surface dried<br>with air flow.           | Culture methods.                                 | Percentage<br>of sites with<br>positive results<br>for Aa* mean<br>values.                                                                                                                                                                                                  | Placement of<br>orthodontic<br>appliance favors<br>subgingival growth<br>of Aa.                                                                                                                                                        |

\* Aa = *Actinobacillus actinomycetemcomitans*

**Table 3 (continuation)** - Characteristics of studies included in the review (detailed quality information).

| Author/<br>Year                     | Study<br>design                                     | Participant                                                                                                                                                                                                                                                                |                                                                                    | Material<br>collection<br>time                                                                                                                                                                                                                                                                    | Collection<br>methods                                                                                           | Microbial<br>analysis<br>methods                 | Statistical<br>analysis                                                                                                  | Conclusion                                                                                                                                                       |
|-------------------------------------|-----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                     |                                                     | Sample<br>standards                                                                                                                                                                                                                                                        | General<br>sample<br>description                                                   | Total study<br>time/ interval<br>times                                                                                                                                                                                                                                                            | Control of factors<br>influencing<br>collection                                                                 | Culture<br>methods/<br>molecular<br>biology/ SEM |                                                                                                                          |                                                                                                                                                                  |
| Ristic et al, <sup>21</sup><br>2007 | Prospective<br>longitudinal<br>controlled<br>study. | Indication for<br>fixed orthodontic<br>therapy; good<br>initial general<br>and periodontal<br>health; lack of<br>antibiotic therapy<br>3 months before<br>and during the<br>study and nonuse<br>of antiplaque and<br>oral antiseptic<br>solutions during<br>investigation. | 32 subjects, 13<br>males and 19<br>females aged<br>between 12 and<br>18 years old. | Collected<br>just before<br>placement of<br>fixed appliances,<br>and 1, 3 and 6<br>months after/<br>Collected<br>from mesio-<br>vestibular points<br>of subgingival<br>sulcus of<br>maxillary right<br>first molar,<br>maxillary left<br>central incisor<br>and maxillary left<br>first premolar. | Subgingival plaque:<br>inserting two sterile<br>paper points (ISO<br>45)/ Collected in dry<br>field conditions. | Culture methods.                                 | Descriptive<br>statistical<br>measures,<br>Student's- t test<br>and chi-square<br>test combined<br>with McNemar<br>test. | In adolescents,<br>fixed orthodontic<br>treatment<br>increases<br>the values of<br>periodontal indices<br>and growth of<br>pathogenic and<br>anaerobic bacteria. |

\* *Aa* = *Actinobacillus actinomycetemcomitans*

carefully collected so as to avoid interference from other sites in the oral cavity.<sup>13,21-24,26,27</sup>

The articles classified as having low methodological quality<sup>5,11,27,28</sup> presented similarities that contributed to their low score and subsequent exclusion from the present review. Follow-up periods did not last for more than three months. Short-term researches are not suitable for investigating the influence of environmental changes in oral microbial colonization.<sup>21,29</sup> These studies did not describe the control of influential factors that could interfere in biological material collection, a critical aspect in the research. Isolation of the area and previous removal of other biological material surrounding the collection site is essential.<sup>13,21-24,26</sup>

Despite the difficulty of isolating and maintaining microbial culture in laboratory, three articles used this method of investigation.<sup>5,11,24,27</sup>

One of them presented the results in an inappropriate manner.<sup>24</sup> There was no comparison among results yielded at different times and no statistical treatment was applied. Andrucio et al<sup>28</sup> was the only one who provided an article that employed molecular biology techniques, however, it was excluded for conducting a one month follow-up. There was a lack of well-designed clinical trials using molecular biology techniques. It is worth noting that they are effective, but expensive methods that should be applied with better defined criteria.

The studies included in this systematic review were classified as having moderate methodological quality.<sup>20,23</sup> Two of them<sup>22,23</sup> were conducted by the same author, however, they presented different objectives, distinct samples and different follow-up periods. Both studies<sup>22,23</sup> implemented similar

methods to control the factors that could influence microbial collection. They conducted prior removal of supragingival plaque with a sterile curette and gingival surface drying with gentle air flow. Culture and subculture methods were selected for bacteriological analysis and definitive bacteria identification. Non-selective as well as selective culture media for *Actinobacillus actinomycetemcomitans* (*Aa*) were used. After incubation, the agar plates with selective culture media (trypticase soy-serum bacitracin vancomycin hydrochloride — TSBV) were examined and the colony-forming unit characteristics of *Aa* were subcultured. Definitive bacteria identification was carried out by means of the following methods: Gram-stain; nitrate reduction; production of catalase; urease and indole; growth on MacConkey agar and fermentation reactions to carbohydrates supplemented with the profiles of the enzymes used.

The first study,<sup>23</sup> carried out in 1997, aimed to assess the occurrence of *Actinobacillus actinomycetemcomitans* (*Aa*) in 70 young patients and to determine if the presence of *Aa* at the baseline could influence the periodontal status 3 years after orthodontic treatment had been performed with fixed appliances. The clinical index for gingival bleeding revealed a significant decrease in the percentage of bleeding sites in orthodontic patients, although they presented more deteriorated gingival status. This could be explained by impaired plaque control caused by the presence of appliances. The mean percentage of positive plaque index remained stable among orthodontic patients during the study, although it was higher when compared with subjects without appliances. The study suggested that the presence of orthodontic appliances decreased the percentage of positive sites for *Aa* among treated patients (from 47.5% at baseline to 25.3% after 3 years). This fact may be associated with a successful host response, able to reduce and control *Aa* in the subgingival sites. The lack of association between subgingival *Aa* and inflammation in orthodontic patients can be due to the overgrowth of other bacterial species that could interfere in the virulence factors of *Aa*.

In 1999, Paolantonio et al<sup>22</sup> aimed at establishing a direct relationship between orthodontic appliance placement and subgingival colonization by *Aa*. They also aimed at determining whether *Aa* colonization occurred only on teeth with appliances, or whether

the presence of appliances could cause the isolation of *Aa* in teeth without appliances. A total of 24 individuals were observed from baseline to 1, 2 and 3 months after appliances had been placed. Results showed a significant increase in *Aa* until the first month of therapy and a stable mean of *Aa* prevalence between the first and the third month. *Aa* was isolated in 83.3% of sites after one month of therapy. Placement of orthodontic appliances was followed by worse gingival conditions with a tendency to bleeding and increase in plaque accumulation. The authors emphasized that the short period during which the study was conducted could have influenced the results, since another longitudinal 3-year study reported marked changes in the proportions of *Aa*.

Among all articles classified as having moderate methodological quality, only one described the study design and the ethical aspects considered for the research.<sup>21</sup> The authors collected biological material at four different time intervals. There were baseline, one, three and six month observations of periodontopathic anaerobe colonizations: *Prevotella intermedia* (*Pi*), *Aa*, *Porphyromonas gingivalis* (*Pg*) and *Fusobacterium nucleatum* (*Fn*). After isolation, bacteria were incubated for later semi-quantitative detection of anaerobe colonies using direct counting and density comparison. Subculturing, Gram-stain and identification tests of biochemical reactions were performed for accurate identification of bacterial species. According to this study, the maximum microbiological values were obtained three months after the beginning of the fixed orthodontic therapy. There was a decrease in microbiological parameters between the third and the sixth month after the appliances had been placed, which was explained based on the re-establishment of host-microorganism balance after the third month of therapy. The results of clinical parameters described an increase in the values of all clinical indices. Plaque index should be emphasized, since it increased until the third month of therapy, when the maximum score was recorded. Subsequently, the index decreased during the last months of investigation. The results confirmed the growth of periodontopathic bacteria in adolescents treated with fixed appliances, however, it was a transient condition.

In the last research included in this review,<sup>20</sup> subgingival collection was performed before and one year after the appliances had been placed. The samples

were collected using 0.016-in stainless steel orthodontic wire 20 mm in length inserted into gingival crevices. After preparation, each sample was plated onto five different selective media for subgingival bacteria. Plates were cultured in an anaerobic chamber at 37°C for four days and the total count of viable bacteria was determined. Results did not show significant changes in subgingival microbiota during investigation, however, the percentage of the five types of bacteria was altered, especially *Streptococci* (17.5% of oral microbiota after one year). The increase in these bacteria is generally related to higher incidence of caries. On the other hand, there was a decrease in the percentage of *Actinomyces* (13.3% decrease in the total flora), and smaller reduction in *Fusobacterium* and *Bacteroides* species. Spirochetes had a statistically insignificant increase. These are potentially pathogenic gram-negative bacteria associated with periodontal disease. The insignificant increase in the number of gram-negative anaerobic bacteria was attributed to relatively good oral hygiene and consequently little increase in plaque accumulation. Therefore, no significant gingival pockets were formed. Clinical indices for periodontal health were used to complement the study. The supragingival index did not significantly change after one year of treatment, however, there was a correlation between orthodontic appliance use and plaque level for both time intervals. The gingival index showed an important increase for bonded teeth. The lack of correlation between gingival index and subgingival changes was also determined, which suggests that subgingival bacteria are not the only type directly responsible for gingival inflammation. The increase in *streptococci* in the supragingival plaque might have contributed to gingival inflammation. Therefore, the authors concluded that the effect of orthodontic fixed appliances on periodontal health should be further investigated and confirmed by studies conducted over longer periods of time.

Moreover, the hypothesis that orthodontic appliances create an ecologic environment favorable to qualitative alterations in the subgingival microbiota, and that orthodontic appliances were associated with

poor oral hygiene and produced transitory gingival alterations incompatible with permanent damage to periodontal structures was accepted.<sup>22</sup> It is extremely important to keep orthodontic patients under strict control of oral hygiene and plaque accumulation in order to favor rebalance between host and microorganism after appliance placement.<sup>21</sup> Proper hygiene control leads to little increase in plaque accumulation in orthodontic patients, minimizing the possibility of tooth decalcification and development of inflammatory periodontal disease.<sup>20</sup> Professional monitoring may motivate patients to maintain better self-performed plaque control and proper oral health.<sup>23</sup>

The results presented in this systematic review indicate that there is moderate scientific evidence that orthodontic fixed appliances influence the oral microbiota, given that no study was classified as presenting high methodological quality. Placement of appliances increases quantity and quality of oral microbiota. Apparently, this is a transitory effect which depends on oral hygiene. However, further well-designed studies conducted within longer periods of investigation, lower interval time between collections and more sensitive and specific microbiological analysis methods are needed to confirm the influence of orthodontic fixed appliances over oral microbiota. This strategy would confirm whether there is a critical period of time for the increase in microbiological colonization after the placement of orthodontic appliances. Therefore, orthodontists should reinforce the need for special oral hygiene control during orthodontic treatment.

## CONCLUSIONS

The literature revealed moderate evidence that the presence of fixed appliances influences the quantity and quality of oral microbiota. This might be a transitional effect that depends on oral hygiene control. The authors recommend that further investigations be developed on the influence of increasing quantity and quality of oral microbiota in the establishment of caries and periodontal diseases.

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# Bibliometric analysis of scientific articles published in Brazilian and international orthodontic journals over a 10-year period

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**Objective:** This study aimed at describing the profiles of Brazilian and international studies published in orthodontic journals.

**Methods:** The sample comprised 635 articles selected from two scientific journals, i.e., Dental Press Journal of Orthodontics and American Journal of Orthodontics and Dentofacial Orthopedics, which were analyzed at three different intervals over a 10-year period (1999 – 2004 – 2009). Articles were described in terms of knowledge domain, study design, and country of origin (or state of origin for Brazilian papers).

**Results:** The most frequent study designs adopted in international studies were cohort (23.9%) and cross-sectional (21.7%) designs. Among Brazilian papers, cross-sectional studies (28.9%) and literature reviews (24.6%) showed greater frequency. The topics most often investigated were dental materials (17%) and treatment devices (12.4%) in international articles, with the latter topic being addressed by 16% of the Brazilian publications, followed by malocclusion, with 12.6%. In all cases, the most frequent countries of origin coincided with the countries of origin of each journal.

**Conclusions:** The majority of the studies analyzed featured a low level of scientific evidence. Moreover, the findings showed that journals tend to publish studies produced in their own country of origin, and that there are marked discrepancies in the number of papers published by different Brazilian states.

**Keywords:** Bibliometrics. Dental research. Orthodontics. Study characteristics.

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## INTRODUCTION

The growing demand for structuring and organizing information gleaned from the scientific and academic domains has allowed healthcare scientists to analyze scientific output in unprecedented detail. Bibliometrics emerges as an important tool that enables one to map and generate different indicators of information management and knowledge.<sup>1-5</sup>

By implementing a bibliometric approach in Orthodontics one can evaluate publications that facilitate information retrieval and stratification. In view of the above, after reviewing, stratifying and electronically storing a catalog comprising the information identified, one can build an accessible database. This database can aid patients and professionals in making decisions about clinical procedures, as well as raise new research topics.<sup>6</sup>

After careful review of the orthodontic literature, Sun et al<sup>6</sup> found clinically relevant information on which to base clinical decisions that struck a balance between etiology, diagnosis, treatment and prognosis. Mavropoulos and Kiliaridis<sup>7</sup> found that articles published in orthodontic journals increasingly focused on treatment evaluation and diagnosis. They further found that the number of investigations into new treatment methods dwindled significantly over the past 20 years, which led them to conclude that there is absolute need for high-quality studies capable of generating reliable scientific evidence.

Nevertheless, few studies in Orthodontics make use of bibliometric analysis, evincing the need for further research carried out on the basis of this methodology.<sup>7,8</sup> Therefore, the aim of this study is to describe the profiles of Brazilian and international publications in two journals of Orthodontics at three different intervals over a period of 10 years (1999 - 2004 - 2009), assessing the knowledge domains and article designs used, while identifying the country of origin of the published studies.

## MATERIAL AND METHODS

The journals used in this research were selected from the Brazilian National Council for Scientific and Technologic Development (CAPES) database. Only those Brazilian and international periodicals which ranked among the best in the area of Orthodontics according to CAPES-QUALIS rating in 2010 were selected. The selected journals were

Dental Press Journal of Orthodontics (Dental Press Publishers, Maringá-PR, Brazil) and American Journal of Orthodontics and Dentofacial Orthopedics (Elsevier Publishers, Amsterdam, The Netherlands).

With the 1999, 2004 and 2009 issues of the selected journals in hand, copies of the abstracts of all articles were analyzed and divided by year and afterwards divided by volume and number. Subsequently, the titles and abstracts were reviewed.<sup>9</sup> The following three variables were assessed: Knowledge domain, study design and countries where the article(s) were published. When it was not possible to characterize these research variables using only the title and the abstract, the full article was obtained and analyzed in the same manner. Two examiners were trained and calibrated to collect information. Their performance was measured by means of the Kappa test, of which result was  $k = 0.9654$  (nearly perfect agreement). Categorization of data was carried out independently by physical, manual and direct review of the abstract of each reference. Preface, editorial, readers' letters and other data pertaining to journal organization were excluded.

Six knowledge domains and 18 specific subdomains were established in order to detect and assess trends in the themes and subjects being addressed. Study designs were ranked as advocated by Fletcher and Fletcher.<sup>10</sup> The countries in the study were identified and named according to the country of origin of each author whose mailing address was disclosed, with the purpose of reaching the total number of publications in each country, thereby detailing their scientific contribution. When the author was Brazilian, their state of origin was also recorded according to their mailing address.

The instrument used to record the data included a specific form containing questions about each knowledge domain, study design and country of publication. The data were then organized and analyzed using Statistical Package for the Social Sciences (SPSS) software, version 10.0, presented by means of descriptive and analytical statistics.

To investigate whether there was a significant association between journals and countries of publication and the other study variables, the chi-square and Fisher's Exact tests were employed. These tests are used to verify the existence of a significant association between two qualitative variables. Fisher's exact test is an alternative to the chi-square test when samples are too small.

## RESULTS

The chi-square and Fisher's exact tests demonstrated that all variables (knowledge domain, study design and year) were significantly correlated with the journals analyzed. In terms of number of publications, there was a substantial difference between journals, indicating that such difference was maintained throughout the study period. This association proved statistically significant ( $p = 0.008$ ) (Table 1).

The cohort, cross-sectional and *in vitro* laboratory studies proved the most frequent publications in the AJO-DO, whereas cross-sectional design, literature review and cohort studies were more

frequently observed in the Dental Press Journal. The design variable was significantly associated with the journals ( $p = 0.000$ ) (Table 2). The areas of Dental Material and Treatment Devices were the most frequently

**Table 1** - Distribution of articles for each journal evaluated..

| Year  | Journal |      |              |      | p      |
|-------|---------|------|--------------|------|--------|
|       | AJO-DO  |      | Dental Press |      |        |
|       | n       | %    | n            | %    |        |
| 1999  | 164     | 35.7 | 40           | 22.9 | 0.008* |
| 2004  | 134     | 29.1 | 63           | 36.0 |        |
| 2009  | 162     | 35.2 | 72           | 41.1 |        |
| Total | 460     | 100  | 175          | 100  |        |

<sup>1</sup> Chi-square test; \* significant  $p \leq 0.01$ .

**Table 2** - Distribution of articles according to the variables evaluated.

| Variable         | Category                      | Journal |      |              |      | P                   |
|------------------|-------------------------------|---------|------|--------------|------|---------------------|
|                  |                               | AJO-DO  |      | Dental Press |      |                     |
|                  |                               | n       | %    | n            | %    |                     |
| Design           | Case-control                  | 1       | 0.2  | -            | -    | 0.000 <sup>2*</sup> |
|                  | Cohort                        | 110     | 23.9 | 30           | 17.1 |                     |
|                  | Non-randomized clinical trial | 13      | 2.8  | 3            | 1.7  |                     |
|                  | Randomized clinical trial     | 28      | 6.1  | 1            | 0.6  |                     |
|                  | <i>In vitro</i> laboratorial  | 87      | 18.9 | 16           | 9.1  |                     |
|                  | <i>In vivo</i> laboratorial   | 33      | 7.2  | 3            | 1.7  |                     |
|                  | Meta-analysis                 | 2       | 0.4  | -            | -    |                     |
|                  | Specialist's opinion          | 5       | 1.1  | -            | -    |                     |
|                  | Case report                   | 50      | 10.9 | 19           | 10.9 |                     |
|                  | Systematic review             | 3       | 0.7  | 2            | 1.1  |                     |
|                  | Literature review             | 20      | 4.3  | 43           | 24.6 |                     |
|                  | Case series                   | 8       | 1.7  | 8            | 4.6  |                     |
|                  | Cross-sectional               | 100     | 21.7 | 50           | 28.6 |                     |
| Knowledge domain | Skeletal anchorage            | 28      | 6.1  | 3            | 1.7  | 0.000 <sup>2*</sup> |
|                  | Temporomandibular joint       | 25      | 5.4  | 5            | 2.9  |                     |
|                  | Cariology                     | 13      | 2.8  | 3            | 1.7  |                     |
|                  | Surgery                       | 32      | 7.0  | 14           | 8.0  |                     |
|                  | Treatment devices             | 57      | 12.4 | 28           | 16.0 |                     |
|                  | Pharmacology                  | 8       | 1.7  | -            | -    |                     |
|                  | Imaging                       | 24      | 5.2  | 17           | 9.7  |                     |
|                  | Dental material               | 78      | 17.0 | 15           | 8.6  |                     |
|                  | Orthodontic mechanics         | 46      | 10.0 | 14           | 8.0  |                     |
|                  | Morphology                    | 48      | 10.4 | 18           | 10.3 |                     |
|                  | Dental malocclusion           | 39      | 8.5  | 22           | 12.6 |                     |
|                  | Legal Dentistry               | -       | -    | 5            | 2.9  |                     |
|                  | Other                         | 16      | 3.5  | 11           | 6.3  |                     |
|                  | Special patients              | 2       | 0.4  | -            | -    |                     |
|                  | Oral pathology                | 17      | 3.7  | 5            | 2.9  |                     |
|                  | Follow-up                     | 8       | 1.7  | 2            | 1.1  |                     |
|                  | Bone and root resorption      | 8       | 1.7  | 8            | 4.6  |                     |
|                  | Mouth breathing               | 1       | 0.2  | 3            | 1.7  |                     |
|                  | Retention                     | 9       | 2.0  | 2            | 1.1  |                     |
|                  | Occlusal index                | 1       | 0.2  | -            | -    |                     |

<sup>2</sup> Fisher's exact teste; \* significant  $p \leq 0.01$ .

found in the AJO-DO. In the Dental Press Journal, on the other hand, Treatment Devices and Dental Malocclusion appeared to be the most frequent domains. Knowledge domain was also significantly associated with the Dental Press Journal ( $p = 0.000$ ) (Table 2).

There were publications from 47 different countries. Both Brazilian and international journals predominantly published texts written by authors of their respective countries of origin. The United States was the country with the greatest number of published studies in the American Journal (162 articles, 35.2%), followed by Brazil (9.1%). Brazilian-authored studies prevailed in the Dental Press Journal, with 174 articles (99.4%) (Table 3).

Brazilian publications comprised cross-sectional studies involving the study of malocclusion, imaging

and morphology. Laboratory studies were generally correlated with research on dental material. Research on surgery and treatment devices are carried out by cohort studies (Table 4).

In international publications, cohort research was most often associated with studies on treatment devices and morphology. *In vitro* laboratory studies, in turn, were found to be significantly linked to research on dental material. Research on morphology, dental malocclusion and imaging occurred most often in cross-sectional studies. In case reports, studies on dental malocclusion prevailed (Table 5).

São Paulo was the Brazilian state which produced the largest number of publications in both the Brazilian and the international journals. Paraná state

**Table 3** - Countries of origin of published articles.

| Country     | AJO-DO |      | Journal |      |
|-------------|--------|------|---------|------|
|             | n      | %    | n       | %    |
| Brazil      | 42     | 9.1  | 174     | 99.4 |
| USA         | 162    | 35.2 | -       | -    |
| Japan       | 37     | 8.0  | -       | -    |
| Turkey      | 24     | 5.2  | -       | -    |
| England     | 19     | 4.1  | -       | -    |
| Canada      | 18     | 3.9  | -       | -    |
| Korea       | 18     | 3.9  | -       | -    |
| Italy       | 17     | 3.7  | -       | -    |
| Germany     | 14     | 3.0  | -       | -    |
| Holland     | 10     | 2.2  | -       | -    |
| Greece      | 8      | 1.7  | -       | -    |
| Israel      | 8      | 1.7  | -       | -    |
| India       | 8      | 1.7  | -       | -    |
| China       | 7      | 1.5  | -       | -    |
| Sweden      | 7      | 1.5  | -       | -    |
| Switzerland | 5      | 1.1  | -       | -    |
| Taiwan      | 5      | 1.1  | -       | -    |
| Austria     | 4      | 0.9  | -       | -    |
| Australia   | 4      | 0.9  | -       | -    |
| Belgium     | 3      | 0.7  | -       | -    |
| Egypt       | 3      | 0.7  | -       | -    |
| Kuwait      | 3      | 0.7  | -       | -    |
| Mexico      | 3      | 0.7  | -       | -    |
| Norway      | 3      | 0.7  | -       | -    |
| Thailand    | 3      | 0.7  | -       | -    |
| Spain       | 2      | 0.4  | -       | -    |
| Finland     | 2      | 0.4  | -       | -    |
| Ireland     | 2      | 0.4  | -       | -    |
| Iceland     | 2      | 0.4  | -       | -    |
| Others      | 17     | 3.7  | 1       | 0.6  |
| Total       | 460    | 100  | 175     | 100  |

Table 4 - Study design in relation to knowledge domain for the Brazilian journal.

| Knowledge domain         | Design |                          |                      |               |              |             |             |                   |             |        |
|--------------------------|--------|--------------------------|----------------------|---------------|--------------|-------------|-------------|-------------------|-------------|--------|
|                          | Cohort | Non-rand. clinical trial | Rand. clinical trial | In vitro lab. | In vivo lab. | Cross sect. | Case report | Literature review | Case series | Others |
| Skeletal anchorage       | 0      | 0                        | 0                    | 0             | 0            | 0           | 2           | 0                 | 1           | 0      |
| Temporomandibular joint  | 0      | 0                        | 0                    | 0             | 0            | 3           | 0           | 2                 | 0           | 0      |
| Cariology                | 1      | 1                        | 1                    | 0             | 0            | 0           | 0           | 0                 | 0           | 0      |
| Surgery                  | 8      | 1                        | 0                    | 0             | 0            | 0           | 0           | 5                 | 0           | 0      |
| Treatment devices        | 9      | 1                        | 0                    | 1             | 0            | 2           | 7           | 6                 | 2           | 0      |
| Imaging                  | 2      | 0                        | 0                    | 1             | 0            | 11          | 0           | 2                 | 1           | 0      |
| Dental malocclusion      | 1      | 0                        | 0                    | 0             | 0            | 11          | 5           | 2                 | 2           | 1      |
| Dental material          | 0      | 0                        | 0                    | 10            | 0            | 2           | 0           | 3                 | 0           | 0      |
| Orthodontic mechanics    | 3      | 0                        | 0                    | 1             | 2            | 1           | 2           | 5                 | 0           | 0      |
| Morphology               | 4      | 0                        | 0                    | 1             | 0            | 12          | 0           | 1                 | 0           | 0      |
| Retention                | 0      | 0                        | 0                    | 0             | 0            | 0           | 1           | 1                 | 0           | 0      |
| Oral pathology           | 1      | 0                        | 0                    | 0             | 1            | 0           | 0           | 1                 | 1           | 1      |
| Follow-up                | 1      | 0                        | 0                    | 0             | 0            | 0           | 0           | 1                 | 0           | 0      |
| Bone and root resorption | 0      | 0                        | 0                    | 0             | 0            | 1           | 2           | 5                 | 0           | 0      |
| Others                   | 0      | 0                        | 0                    | 2             | 0            | 7           | 0           | 9                 | 1           | 0      |

Table 5 - Study design in relation to knowledge domain for the international journal.

| Knowledge domain         | Design |                          |                      |               |              |             |             |                   |             |        |
|--------------------------|--------|--------------------------|----------------------|---------------|--------------|-------------|-------------|-------------------|-------------|--------|
|                          | Cohort | Non-rand. clinical trial | Rand. clinical trial | In vitro lab. | In vivo lab. | Cross sect. | Case report | Literature review | Case series | Others |
| Skeletal anchorage       | 5      | 0                        | 1                    | 3             | 5            | 6           | 5           | 0                 | 1           | 2      |
| Temporomandibular joint  | 7      | 0                        | 0                    | 2             | 4            | 9           | 0           | 0                 | 2           | 1      |
| Cariology                | 3      | 1                        | 3                    | 4             | 2            | 0           | 0           | 0                 | 0           | 0      |
| Surgery                  | 13     | 1                        | 2                    | 2             | 3            | 1           | 9           | 1                 | 0           | 0      |
| Treatment devices        | 26     | 7                        | 9                    | 4             | 1            | 3           | 5           | 0                 | 0           | 2      |
| Pharmacology             | 0      | 1                        | 2                    | 0             | 4            | 0           | 0           | 0                 | 0           | 1      |
| Imaging                  | 2      | 0                        | 0                    | 4             | 0            | 15          | 0           | 2                 | 1           | 0      |
| Dental malocclusion      | 3      | 0                        | 2                    | 0             | 0            | 20          | 12          | 2                 | 0           | 0      |
| Dental material          | 4      | 0                        | 6                    | 59            | 2            | 1           | 2           | 4                 | 0           | 0      |
| Orthodontic mechanics    | 10     | 2                        | 2                    | 6             | 8            | 5           | 8           | 1                 | 1           | 3      |
| Morphology               | 17     | 1                        | 0                    | 2             | 2            | 23          | 0           | 3                 | 0           | 0      |
| Retention                | 2      | 0                        | 0                    | 0             | 0            | 0           | 3           | 3                 | 1           | 0      |
| Oral pathology           | 7      | 0                        | 0                    | 1             | 0            | 4           | 2           | 1                 | 2           | 0      |
| Follow-up                | 7      | 0                        | 0                    | 0             | 0            | 0           | 1           | 0                 | 0           | 0      |
| Bone and root resorption | 2      | 0                        | 0                    | 0             | 2            | 3           | 1           | 0                 | 0           | 0      |
| Others                   | 2      | 0                        | 1                    | 0             | 0            | 10          | 2           | 3                 | 0           | 2      |

**Table 6** - State of origin of Brazilian published articles.

| State               | AJO-DO |       | Journal |       |
|---------------------|--------|-------|---------|-------|
|                     | n      | %     | n       | %     |
| Outside Brazil      | 418    | 90.9  | 1       | 0.6   |
| Alagoas             | -      | -     | 1       | 0.6   |
| Bahia               | -      | -     | 4       | 2.3   |
| Ceará               | -      | -     | 1       | 0.6   |
| Distrito Federal    | 1      | 0.2   | 2       | 1.1   |
| Espírito Santo      | -      | -     | 1       | 0.6   |
| Goiás               | -      | -     | 2       | 1.1   |
| Maranhão            | -      | -     | 2       | 1.1   |
| Mato Grosso do Sul  | -      | -     | 2       | 1.1   |
| Minas Gerais        | 7      | 1.5   | 15      | 8.6   |
| Pará                | -      | -     | 2       | 1.1   |
| Paraíba             | -      | -     | 2       | 1.1   |
| Paraná              | 2      | 0.4   | 24      | 13.7  |
| Pernambuco          | 1      | 0.2   | 2       | 1.1   |
| Piauí               | -      | -     | 1       | 0.6   |
| Rio de Janeiro      | 4      | 0.9   | 17      | 9.7   |
| Rio Grande do Norte | -      | -     | 3       | 1.7   |
| Rio Grande do Sul   | 4      | 0.9   | 6       | 3.4   |
| Santa Catarina      | -      | -     | 5       | 2.9   |
| São Paulo           | 23     | 5.0   | 82      | 46.9  |
| Total               | 460    | 100.0 | 175     | 100.0 |

ranked second in frequency of publications in the Brazilian journal. Minas Gerais state achieved the second highest frequency in the international journal and stood out, along with Rio de Janeiro state, in the Brazilian journal (Table 6).

## DISCUSSION

Contemporary Orthodontics has shown a considerable interest in themes that contribute to strengthening the interaction between scientific evidence and clinical decisions. As a result, the quality of studies available in the literature is an important factor which requires investigation. This study performed a bibliometric analysis of orthodontic literature with the purpose of characterizing scientific output in this

research area. Brazilian and international abstracts of high-ranking scientific journals were used. Journals constitute not only an important communication channel for science, but also the most extremely dynamic method employed to disseminate knowledge developed in this dental specialty domain. These periodicals also convey the scientific output of a specific area. Furthermore, they boast utmost credibility and widespread dissemination among dental professionals.

Setting criteria to assess the influence of each scientific journal has aroused fruitful debates. The influence of a given journal can be determined in various ways such as by citation index, measured by impact factor (IF) or through its wide acceptance as indicated by how extensively it circulates. Kanavakis et al<sup>8</sup> adopted the impact

factor index as an inclusion criterion in their orthodontic bibliometric investigation. This analysis used CAPES-QUALIS as its frame of reference, since no Brazilian orthodontic journal currently has an impact factor.

In this study, as in the study conducted by Poletto and Faraco Júnior,<sup>11</sup> all data were collected by exploratory reading of the title and abstract carried out by two specialists in Orthodontics, who worked separately and concurrently after training and calibration in order to impart reliability to the assessment and avoid measurement bias, as described in Nainar's study.<sup>12</sup>

Analysis of the articles comprised the years 1999, 2004 and 2009, spanning a period of 10 years, totaling 635 articles. Throughout the study period, the Brazilian journal published an increasing number of articles while the international journal remained superior and constant in the number of publications. It is worth noting that the Brazilian journal is a bimonthly publication of which inception occurred 16 years ago. The international journal, in turn, is a monthly publication launched 97 years ago. In the study carried out by Gibson et al,<sup>13</sup> all articles published between 1999 and 2008 were collected, 425 of which were randomly analyzed so as to determine the publishing profile of four international orthodontic journals. With a view to assessing the methodology and quality of systematic reviews in Orthodontics, Papageorgiou et al<sup>14</sup> resorted to electronic searches. In this research, however, collecting all articles published at 3 different intervals made it possible to compare trends in these publications over the years.

Harrison et al.<sup>15</sup> found significant differences in the content of international journals of Orthodontics, suggesting that journals can depict different aspects of the specialty. An insight into the publishing trends of various journals can help clinicians to identify journals that are best suited to meet their needs.

Out of all research conducted by Gibson and Harrison,<sup>13</sup> articles on growth and development, diagnosis and treatment accounted for 72.2% of the articles analyzed. This research showed similarity between the Brazilian and the international journal in terms of the domains studied, since the results indicate a trend towards the performance of studies on treatment devices and morphology in both journals. When classifying the knowledge domains in this investigation, under the "treatment devices" variable, for example, studies which aimed at assessing the efficacy and therapeutic

characteristics of various appliances used in orthodontic treatment were included. In addition, studies on facial and bone analysis, as well as growth characteristics, among others, were included under morphology, in the respective knowledge domain. Thus, it was noted a trend towards interventional studies, suggesting interest in therapeutic clinical resolutions and their respective responses in the maxillofacial complex. The international journal published studies on dental material (17%) with a higher frequency. These studies evaluated, for example, mechanical and adhesive properties, or rate of poisoning of the material involved in the treatment. A plausible explanation for this percentage is the modernization of material, development of new products and methods of evaluation.

Epidemiological studies on malocclusion — dental abnormalities — were classified in the knowledge domain under "dental malocclusion," and had the second highest frequency rate (12.6%) in the Brazilian journal. These studies enable the implementation of preventive measures based on epidemiological surveys on the prevalence of malocclusion, which also provide an important foundation to assess the current condition and future oral healthcare needs of a population.

The cohort (23.9%) and cross-sectional (21.7%) study designs were the most frequent in the international journal. In the Brazilian journal, however, cross-sectional studies showed a 28.6% frequency, with literature reviews ranking second with 24.6%.

Laboratory studies are usually an important step that allow new treatment devices or material to be tested in animals to detect potential complications and unexpected results. These studies were highlighted in the international journals, showing a frequency rate of 26.1% when incorporated to *in vitro* and *in vivo* laboratory studies. Although they are necessary to establish basic quality parameters prior to application of material and techniques in humans, *in vitro* studies do not set guidelines for clinical conduct, nor do they afford critical information for clinical decision-making.<sup>16</sup>

Cross-sectional studies are a useful tool for describing characteristics of a population, identifying at-risk groups, for healthcare measures and planning, in addition to enabling research on the potential causal relationships between factors suspected of entailing risk or disease.<sup>17</sup> In the present study, cross-sectional studies prevailed in the Brazilian journal (28.6% vs. 21.7% in

the international journal). In Brazilian and international publications, cross-sectional studies were most frequently performed in research conducted on imaging, dental malocclusion and morphology.

Cohort studies are designed to investigate changes over time, i.e., to monitor a sequence of events.<sup>18</sup> In the publications analyzed in this study, cohort research was often related to studies on treatment devices and morphology in the international journal, whereas it was related to surgery in the Brazilian publication.

Case reports and case series play a significant part in the scientific literature, as noted in this study. In their study, Kanavakis et al<sup>8</sup> reviewed three international journals and found that case reports accounted for 8.89% of the designs evaluated (AJO-DO only: 11.06%). These results resemble those found in this study, if case reports and case series are grouped together (12.6% in AJO-DO, and 15.5% in the Dental Press Journal).

Randomized clinical trials provide the best evidence quality available, and, therefore, it is extremely important to assess how they are conducted and reported. The results of randomized clinical trials influence decision-making in clinical practice and constitute the backbone of systematic reviews.<sup>14,19</sup> A study conducted by Shimada et al<sup>20</sup> identified 161 randomized clinical trials in orthodontic journals issued between 2003 and 2007. This study showed that in both journals there were only a few clinical trials. Additionally, one can expect the number of well conducted trials to be even lower, considering design criteria such as actual randomization of the trial groups, presence of a control group, blinding and standardization of criteria. Thus, the data are in line with research by Pandis et al<sup>19</sup> who found that the quality of randomized clinical trials in the main Dentistry journals can be considered low, and warned that study design is of paramount importance to improve dental treatment. Gibson and Harrison,<sup>13</sup> however, estimate that the number of randomized clinical trials in orthodontic journals has risen dramatically in recent years.

In this study, systematic reviews and meta-analyses accounted for less than 1% of all reviewed articles, underscoring the need for expanding knowledge of evidence-based methods among researchers of Orthodontics as well as in the general area of Dentistry. Defined by the literature as of moderate quality, no significant improvement was observed in these designs over the last decade.<sup>14</sup>

Literature reviews (24.6%) ranked second in the studies published in the Brazilian journal. This type of article can provide summaries of a particular subject, including relevant, updated information. Authors, however, usually employ informal and subjective methods when collecting and interpreting the studies, which could lead them to expose their own biases. In the hierarchy of studies, these are classified as low-power studies as they provide little evidence.

To determine article provenance, the methodology used by Yang and Zhao<sup>21</sup> was applied and publications from 47 different countries were recorded. Most Brazilian and international journals predominantly published texts written by authors of their respective countries of origin. U.S. authors had the largest number of articles published in the American Dental Journal, with 162 (35.2%), while most studies published in the Dental Press Journal were written by Brazilian authors, i.e., 174 articles (99.4%).

Remarkably, it was found that journals tend to publish articles authored in their country of origin. Among the possible explanations for this phenomenon — and this seems to be the case of the Dental Press Journal — are the language in which the journal publishes the articles, and the databases used to index it. In 2010, the Brazilian journal began to be officially published in the English language as well. Nevertheless, it continues to be published in Brazilian Portuguese, in both print and electronic media. This change aimed at meeting the requirements of evaluation and indexation agencies in terms of visibility, impact factor and citation index of the journal.

According to Kanavakis et al,<sup>8</sup> articles hailing from the U.S. made the bulk of AJO-DO publications. Moreover, the researchers reported that most texts published in the European Journal of Orthodontics (EJO) originated from Europe, further illustrating the trend towards publishing articles authored in the country of origin of the journal.

Brazil ranked second in the number of articles published in the AJO-DO. Dental research in Brazil has made major strides in recent years, mainly buoyed by the widespread circulation of specific-area journals and scientific papers presented at scientific meetings.<sup>22,23</sup> According to Suehiro et al,<sup>24</sup> this fact is basically due to an increase in the number of theses and dissertations published, the proliferation of undergraduate and graduate programs, a greater diversity of themes,

innovation and methodological resources as well as strong social commitment, among others.

São Paulo state produced the largest number of publications in both Brazilian and international journals. Paraná state ranked second in frequency of Brazilian publications. Minas Gerais achieved the second highest frequency in the international journal and stood out, along with Rio de Janeiro state, in the Brazilian journal (Table 6). São Paulo boasts a larger number of universities and graduate programs in Dentistry, in addition to being the state with the largest GDP in Brazil, fostering research and the submission of an increasingly significant number of articles for publication.

The search for data in journals, which can be used to support professional decision-making, should be an ongoing process, based on the principles of evidence-based practice. Therefore, evaluating and employing articles that may provide grounds for informed clinical decision-making is part of continuing education for dental students and professionals alike. It should be

emphasized that, ultimately, deploying strategies such as these can improve the efficiency of readers who aim at incorporating research results in their daily practice.

## CONCLUSIONS

Based on the methods used in this study, it is reasonable to conclude that most published articles involve studies with a low potential to generate evidence-based, scientific knowledge, thereby demonstrating that further research — grounded in better quality designs — is warranted. Furthermore, the literature reflects ongoing trends in clinical orthodontic practice, and discloses a relative similarity between Brazilian and international journals regarding the publication of studies on dental material and devices/appliances used in clinical practice. The need for laying down criteria regulating scientific output and publication in Brazilian graduate Dentistry programs, aided by the quality of Brazilian Orthodontics, can help to shed further light on the data presented in this article.

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# Photometric analysis of esthetically pleasant and unpleasant facial profile

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**Objective:** To identify which linear, angular and proportionality measures could influence a profile to be considered esthetically pleasant or unpleasant, and to assess sexual dimorphism.

**Methods:** 150 standardized facial profile photographs of dental students of both sexes were obtained and printed on photographic paper. Ten plastic surgeons, ten orthodontists and ten layperson answered a questionnaire characterizing each profile as pleasant, acceptable or unpleasant. With the use of a score system, the 15 most pleasant and unpleasant profiles of each sex were selected. The photographs were scanned into AutoCAD computer software. Linear, angular and proportion measurements were obtained using the software tools. The average values between groups were compared by the Student's t-test and the Mann-Whitney test at 5%.

**Results:** The linear measures LL-S, LL-H, LL-E, LL-B and Pn-H showed statistically significant differences ( $p < 0.05$ ). Statistical differences were also found in the angular measures G'.Pn.Pg', G'.Sn.Pg' and Sn.Me'.C and in the proportions G'-Sn:Sn-Me' and Sn-Gn':Gn'-C ( $p < 0.05$ ). Differences between sexes were found for the linear measure Ala-Pn, angles G'-Pg'.N-Pn, Sn.Me'.C, and proportions Gn'-Sn:Sn-Me' and Ala-Pn:N'-Sn. ( $p < 0.05$ ).

**Conclusion:** The anteroposterior position of the lower lip, the amount of nose that influences the profile, facial convexity, total vertical proportion and lip-chin proportion appear to influence pleasantness of facial profile. Sexual dimorphism was identified in nasal length, nasofacial and lower third of the face angles, total vertical and nasal height/length proportions.

**Keywords:** Esthetics. Photography. Orthodontics.

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

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## INTRODUCTION

Facial esthetics is considered a significant factor with regard to the perceptions of society and individuals in relation to themselves. Additionally, it plays an important role in the assessment of personality and social acceptance.<sup>1</sup> The ability in recognizing a beautiful face is innate,<sup>2</sup> and the development of esthetic perception happens since childhood.<sup>1,3</sup>

A good facial esthetics is one of the factors that influences the judgement of beauty which is related to the individual's relationship with society, thus enhancing self-esteem.<sup>1</sup> 80% of adults seeking orthodontic treatment for themselves or their children do so based on esthetic motivations, regardless of functional and structural conditions.<sup>4</sup> Therefore, as the goal of most patients is having an esthetically pleasing face, orthodontic treatment plays an important role by modifying the position of teeth, bones and associated soft tissues.

In this context, orthodontic treatment should aim not only at correcting the position of teeth in the bone bases, but also at achieving the best possible facial configuration, associating a harmonious face with an ideal occlusion.<sup>5</sup> It is known that the results obtained from the cephalometric normative values oftentimes do not correspond with the individual patterns of each patient.<sup>1,6</sup> Many authors have attempted to define the facial features responsible for a pleasant facial esthetics and observed that the constituent parts of a facial profile, when in harmony and balance, were associated with facial pleasantness.<sup>7</sup>

Studying facial profile through soft tissues has become object of interest among professionals in the orthodontic field over the years. This analysis can be used to assess the face not only in terms of changes induced by orthodontic treatment or growth, but also facial esthetics,<sup>8</sup> considered as the best determinant of orthodontic treatment outcomes.<sup>9</sup>

There are several methods used to analyze craniofacial morphology in facial profile, one of which is achieved at the expense of standardized photographs which occupy a prominent place in facial analysis, being routinely performed by most orthodontists.<sup>5</sup> Photographs provide a good assessment of harmony between the external craniofacial structures, including the contribution of soft tissues, in addition to providing reliable measurements,<sup>10</sup> allowing a quick capture of facial image, having long-term durability and the

possibility of taking repeated measurements.<sup>11</sup> Through photometric analysis of the facial profile, proportionality, angular and linear measurements can be obtained. To many researchers, these measures serve as a parameter to better define normal conditions, harmony and balance of the profile.<sup>12</sup>

Several studies have tried to find the characteristics responsible for facial pleasantness, classifying facial profiles by subjective analysis of photographs, noting orthodontists and laypeople's point of view.<sup>1,3,13,14</sup> Others have sought to study some characteristics that can influence the esthetics of the profile,<sup>9,12,15</sup> however, what makes a facial profile to be considered more esthetic is not yet fully understood by all clinicians.<sup>16</sup>

Therefore, this study aimed at assessing through standardized photographs which linear, angular and proportionality measures differ from profiles classified as esthetically pleasant and unpleasant.

## MATERIAL AND METHODS

This research was approved by the Federal University of Alagoas Institutional Review Board and was registered under the number 007455/2009-43. The participants who were photographed as well as the evaluators signed a consent form.

For this study, 150 (75 males and 75 females) dental students, aged between 17 years and 9 months to 32 years old, were selected. In selecting the sample, the following inclusion criteria were applied: the subjects should be caucasian; mesofacial; should not wear orthodontic appliances or any other intraoral device that could influence the profile; and should not present facial asymmetry or evident vertical or sagittal discrepancy. Sample size was defined on the basis of convenience, gathering the largest number of students who agreed to participate in the study. Due to the difficulties of scientifically defining race and ethnicity, and because of the great racial mixture of Brazilian people, race was classified by skin color in Caucasian, Mongoloid and Melanoderm. This classification method is widely used in Orthodontics, and for this study, only Caucasians were selected.

Standardized photographs of the right profile were taken with a digital camera, (Canon Rebel, Tokyo, Japan), model Rebel EOS XS, 100 macro lens and macro ring lite flash model MR-14EX, (Canon, Japan). In order to standardize the photographs, they were

obtained by a single operator, in the same environment, at the same distance between the research subject and the camera. Moreover, all the other photographic parameters were also standardized, namely: aperture f11, shutter speed 1/125 and ISO 200. Patients were at rest position, completely relaxed and positioned in a cephalostat (Fig 1).

The photographs were printed on Kodak glossy photo paper (Kodak do Brasil, São José dos Campos, Brazil), size 15x21, using a Noritsu 1501 professional printer (Noritsu Koki Co Ltd, Tokyo, Japan). They were divided into two books, one comprising male photographs and another comprising female photographs, which were delivered to the evaluators — 10 orthodontists, 10 plastic surgeons and 10 laypeople — at their workplaces. The evaluators had to answer to a questionnaire, and for each photograph there were three choices: esthetically pleasant, acceptable or unpleasant facial profile. After the questionnaires were collected, a score system was applied. The photographs classified as presenting an esthetically pleasant profile received a score of +1, acceptable profile was scored with 0 and unpleasant profile with -1. Thus, each photograph could receive a total score that ranged from -30 to +30. This scoring system was only used to select the 15 most pleasant and unpleasant photographs, with no descriptive statistics being performed on the data obtained, only the total sum of points was performed. This study did not assess the differences in perception of different groups of evaluators. The latter were used to ensure that the different concepts of facial esthetics of professional and lay groups were present in the selection of pleasant and unpleasant profiles. Afterwards, the 15 males and 15 females' photographs with the highest scores were selected as representative of an esthetically pleasant profile, whereas the 15 males and 15 females' with the lowest scores were selected as esthetically unpleasant. In selecting the esthetically pleasant facial profiles, should there be a draw score, the following tie-breakers were used in the following priority order: photograph with the highest number of +1 scores, with the greatest number of 0 scores and the lowest number of -1 scores; classification or not in the assessment of the 30 evaluators. In selecting the esthetically unpleasant facial profiles, should there be a draw score, the following tie-breakers were used in the following order of priority: photograph with the

highest number of -1 scores, with the highest number of 0 scores and the lowest number of +1 scores; classification or not in the assessment of the 30 evaluators.

After that, the photographs were scanned on a HP G2410 scanner (Hewlett-Packard Company, Palo Alto, Cali, USA), under 300 dpi resolution, and saved in the AutoCAD 2007 software (Autodesk, Inc, San Rafael, Cali, USA).

To eliminate distortion between the actual size of the face and the size of the photograph, the metal screw of the cephalostat, which is well defined on the photograph, served as a reference. Its actual size was measured with the use of a digital caliper. The actual diameter of the screw of the cephalostat is 15.79 mm. Thus, a circle with the same diameter of the cephalostat screw was designed in the AutoCad software. Then, the images of the screws in each photograph were adjusted to fit the circle drawn in the software. Consequently, the measurements obtained in the software are equivalent to the actual measurements, thus, eliminating the need for obtaining a correction factor.

The facial points markings and measurements were performed by the same operator. The markings were done in two days and the measurements were taken within 6 days (10 photos a day) in order to avoid fatigue and, as a consequence, operator's error. The photographic reference points were selected according to previous studies conducted by Trevisan and Gil<sup>8</sup> as well as Sutter and Turley,<sup>17</sup> as shown in Figure 1.

For profile analysis, the reference lines used in the cephalometric analysis of Steiner, Holdaway, Ricketts and Burstone were drawn to obtain linear measurements that assess the distance from points UL, LL, and Pn to these lines, as shown in Figure 2. As for measurement of nasal length, the distance between the Ala-Pn points was measured. Angular and proportionality measurements were obtained according to Trevisan and Gil<sup>8</sup> as well as Sutter and Turley<sup>17</sup> using an AutoCAD software tool. Such measurements are shown in Figures 3 and 4, respectively.

### Statistical analysis

The data obtained were tabulated and statistically analyzed. Initially, the Kolmogorov-Smirnov normality test with a significance level set at 5% was used to evaluate the distribution pattern of the data. To compare the means of the variables with normal

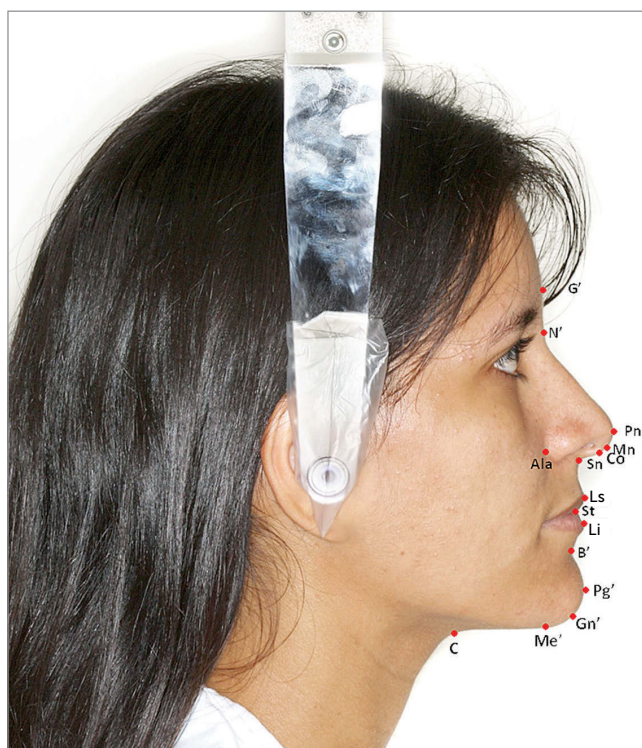


Figure 1 - Photographic reference points.

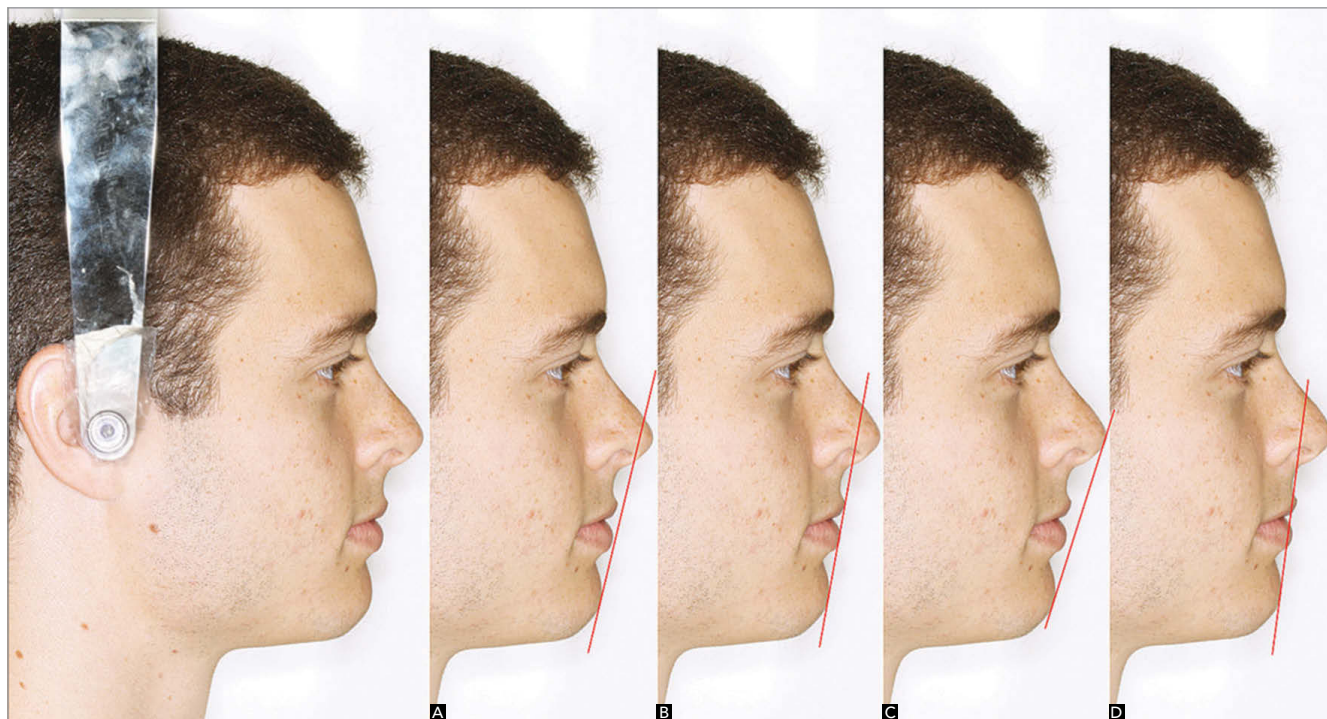


Figure 2 - Reference lines - A) Steiner S line; B) Holdaway H line; C) Ricketts E line D) Burstone B line.

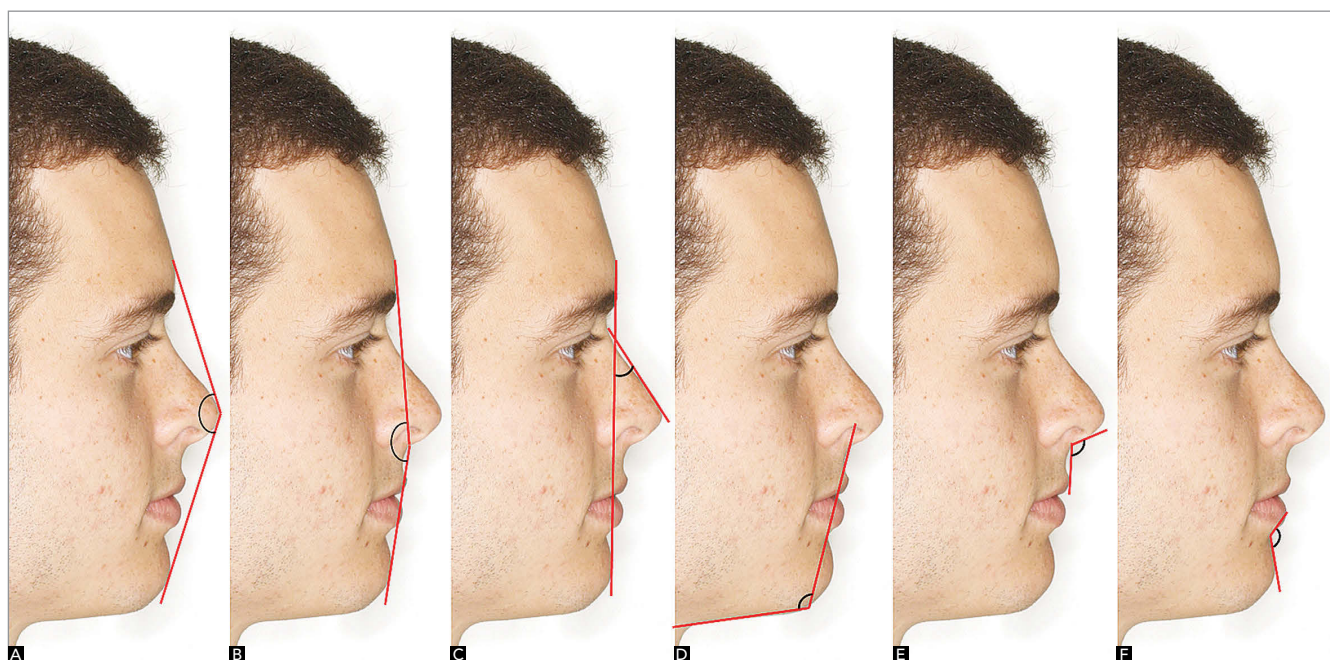


**Figure 3** - Angular measurements and reference lines: **A**) Total facial convexity angle ( $G'.Pn.Pg'$ ); **B**) Facial convexity angle ( $G'.Sn.Pg'$ ); **C**) Nasofacial angle ( $G'.Pg'.N'.Pn$ ); **D**) Lower third angle ( $Sn.Me'.C$ ); **E**) Nasolabial angle ( $UL.Sn.Co$ ); **F**) Mentolabial angle ( $Pg'.B'.LL$ ).

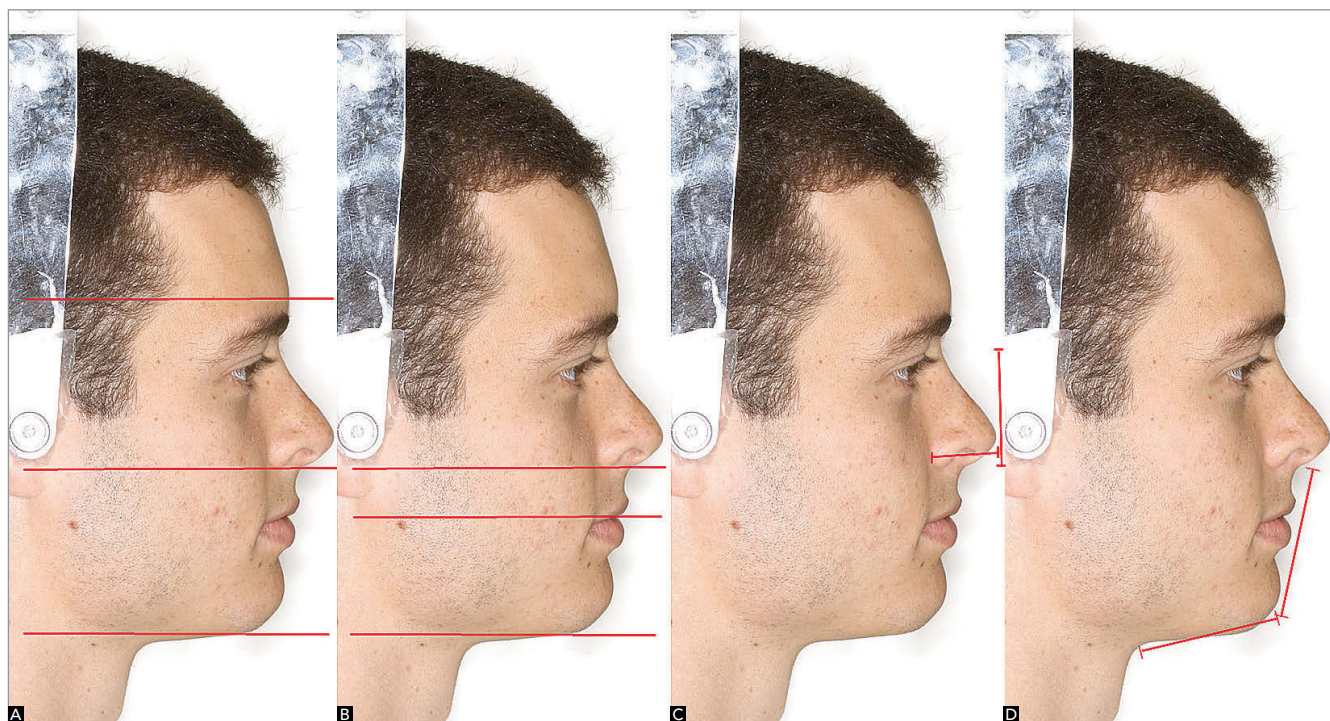


**Figure 4** - Measures of proportionality used in this study: **A**) Total vertical proportion ( $G'.Sn:Sn-Me'$ ); **B**) Inferior third of the face proportion ( $Sn-St:St-Me'$ ); **C**) Nasal height / length proportion ( $Ala-Pn:N'-Sn$ ); **D**) Lip-chin proportion ( $Sn-Gn':Gn'-C$ ).

distribution, a parametric test (Student's t-test) was used, and for variables not normally distributed the non-parametric Mann-Whitney test was used, both with a significance level set at 5%.

### Method error

For intra-examiner error, 30 days after the measurements had been taken, 1/3 of the measures of all variables were repeated and the first and second measures were compared. The random error was calculated in accordance with the formula proposed by Dahlberg and advocated by Houston.<sup>18</sup> The deviation values were acceptable below 1 mm for the linear measurements, and 1.5° for angular measurements. The systematic error was analyzed by paired Student's t-test for the measures that were normally distributed, whereas the Wilcoxon test was used for measures that were not normally distributed, both with a significance level set at 5%.

## RESULTS

In order to test the hypothesis that the variables follow a normal distribution, the normality test of Kolmogorov-Smirnov, with a significance level set at 5%, was employed. It showed that all linear measurements presented normal distribution, which allowed the use of a parametric test (Student's t-test) when comparing the means. However, total facial convexity, nasofacial angles measurements and lip-chin proportion did not present normal distribution. For this reason, the non-parametric test of Mann-Whitney, with a significance level set at 5%, was used.

Random errors were detected in only two variables: angle of the lower third of the face and nasolabial angle. In assessing the systematic error, significant differences were found in only two out of 19 variables: angle of the lower third of the face and lip-chin proportion. As shown in Table 1, which expresses the statistical results

of comparison between the linear measures of the two groups, all variables that assessed the position of the lower lip in relation to the reference lines (LL-S, LL H, LL-E, LL-B) and the distance Pn-H values, showed statistical significance differences ( $p < 0.05$ ).

The results presented in Table 1 show that the angular measurements (total facial convexity angle, facial convexity angle and angle of the lower third of the face), and the proportionality measurements (total vertical proportion and lip-chin proportion) showed  $p$  values  $< 0.05$ .

As for the assessment of sexual dimorphism, according to the Komogorov-Smirnov normality test at 5%, the following measures did not present a normal distribution in the pleasant profile group: angle of the lower third of the face, nasal length/ height and lip-chin proportions. In the unpleasant profile group, nasofacial, nasolabial and mentolabial angles did not have a normal distribution either.

Table 2 reveals sexual dimorphism in nasal length, nasofacial and angle of the lower third of the face, total vertical, nasal height/length proportions in the pleasant profile group. Differences between sexes were observed in the unpleasant profile group, in the linear measure nasal length, angle of the lower third of the face and the total vertical proportion.

## DISCUSSION

Among the many goals of orthodontic treatment, proper teeth intercuspation and relationship with the skeletal bases, stability of results, correct occlusal function and, at present, due to the great emphasis that has been given to esthetics, a harmonious facial profile, have taken a prominent position on the objectives to be achieved at the end of orthodontic treatment.

In order to meet the esthetic expectations of patients, orthodontic treatment must include a detailed analysis of the facial profile. For many years, lateral

**Table 1** - Statistical results of comparison between groups.

| Variables                 | Groups             | n  | Mean $\pm$ SD      | P value |
|---------------------------|--------------------|----|--------------------|---------|
| UL-S                      | Pleasant profile   | 30 | -1.86 $\pm$ 1.34   | 0.176   |
|                           | Unpleasant profile | 30 | -1.18 $\pm$ 2.35   |         |
| LL-S                      | Pleasant profile   | 30 | -0.56 $\pm$ 1.50   | 0.014*  |
|                           | Unpleasant profile | 30 | 0.97 $\pm$ 2.93    |         |
| LL-H                      | Pleasant profile   | 30 | 0.41 $\pm$ 1.00    | 0.001*  |
|                           | Unpleasant profile | 30 | 1.77 $\pm$ 1.95    |         |
| Pn-H                      | Pleasant profile   | 30 | 9.52 $\pm$ 2.21    | 0.006*  |
|                           | Unpleasant profile | 30 | 11.80 $\pm$ 3.76   |         |
| LL-E                      | Pleasant profile   | 30 | -2.02 $\pm$ 1.60   | 0.023*  |
|                           | Unpleasant profile | 30 | -0.49 $\pm$ 3.18   |         |
| UL-E                      | Pleasant profile   | 30 | -4.04 $\pm$ 1.60   | 0.259   |
|                           | Unpleasant profile | 30 | -3.32 $\pm$ 3.07   |         |
| UL-B                      | Pleasant profile   | 30 | 3.59 $\pm$ 1.36    | 0.256   |
|                           | Unpleasant profile | 30 | 4.16 $\pm$ 2.39    |         |
| LL-B                      | Pleasant profile   | 30 | 2.75 $\pm$ 1.40    | 0.010*  |
|                           | Unpleasant profile | 30 | 4.36 $\pm$ 2.94    |         |
| Nasal length              | Pleasant profile   | 30 | 2.45 $\pm$ 0.20    | 0.147   |
|                           | Unpleasant profile | 30 | 2.54 $\pm$ 0.28    |         |
| Tot. facial convex angle  | Pleasant profile   | 30 | 142.67 $\pm$ 4.72  | 0.004#  |
|                           | Unpleasant profile | 30 | 139.10 $\pm$ 4.95  |         |
| Facial convex angle       | Pleasant profile   | 30 | 169.20 $\pm$ 3.88  | 0.003*  |
|                           | Unpleasant profile | 30 | 165.17 $\pm$ 5.81  |         |
| Angle of the lower third  | Pleasant profile   | 30 | 104.10 $\pm$ 6.63  | 0.006*  |
|                           | Unpleasant profile | 30 | 110.17 $\pm$ 9.49  |         |
| Nasofacial angle          | Pleasant profile   | 30 | 32.73 $\pm$ 2.77   | 0.123   |
|                           | Unpleasant profile | 30 | 33.43 $\pm$ 3.01   |         |
| Nasolabial angle          | Pleasant profile   | 30 | 104.37 $\pm$ 7.25  | 0.951   |
|                           | Unpleasant profile | 30 | 104.53 $\pm$ 12.91 |         |
| Mentolabial angle         | Pleasant profile   | 30 | 137.10 $\pm$ 8.79  | 0.187   |
|                           | Unpleasant profile | 30 | 140.40 $\pm$ 10.31 |         |
| Total vertical proportion | Pleasant profile   | 30 | 0.95 $\pm$ 0.08    | 0.022*  |
|                           | Unpleasant profile | 30 | 1.01 $\pm$ 0.10    |         |
| Inferior third position   | Pleasant profile   | 30 | 0.48 $\pm$ 0.05    | 0.600   |
|                           | Unpleasant profile | 30 | 0.47 $\pm$ 0.06    |         |
| Nasal height/length prop. | Pleasant profile   | 30 | 0.74 $\pm$ 0.09    | 0.400   |
|                           | Unpleasant profile | 30 | 0.72 $\pm$ 0.08    |         |
| Lip/chin prop.            | Pleasant profile   | 30 | 1.34 $\pm$ 0.18    | 0.003#  |
|                           | Unpleasant profile | 30 | 1.58 $\pm$ 0.33    |         |

\* Statistical significance ( $p < 0.05$ ) using Student's parametric t test;# Statistical significance ( $p < 0.05$ ) using Mann-Whitney non-parametric test.

**Table 2** – Statistical results of comparison between males and females of the pleasant and unpleasant profile groups.

| Variables                 | Sex    | Pleasant          |         | Unpleasant         |         |
|---------------------------|--------|-------------------|---------|--------------------|---------|
|                           |        | P value           | p-value | Mean $\pm$ SD      | P value |
| UL-S                      | Male   | -1.72 $\pm$ 1.26  | 0.587   | -1.07 $\pm$ 1.74   | 0.815   |
|                           | Female | -1.99 $\pm$ 1.45  |         | -1.28 $\pm$ 2.90   |         |
| LL-S                      | Male   | -0.87 $\pm$ 1.33  | 0.276   | 0.75 $\pm$ 2.65    | 0.684   |
|                           | Female | -0.26 $\pm$ 1.64  |         | 1.19 $\pm$ 3.26    |         |
| LL-H                      | Male   | 0.10 $\pm$ 0.75   | 0.089   | 1.45 $\pm$ 2.04    | 0.378   |
|                           | Female | 0.72 $\pm$ 1.14   |         | 2.09 $\pm$ 1.88    |         |
| Pn-H                      | Male   | 9.75 $\pm$ 2.14   | 0.566   | 12.37 $\pm$ 3.58   | 0.411   |
|                           | Female | 9.28 $\pm$ 2.32   |         | 11.22 $\pm$ 3.98   |         |
| LL-E                      | Male   | -2.35 $\pm$ 1.28  | 0.272   | -0.75 $\pm$ 2.94   | 0.654   |
|                           | Female | -1.69 $\pm$ 1.86  |         | -0.22 $\pm$ 3.48   |         |
| UL-E                      | Male   | -3.78 $\pm$ 1.57  | 0.382   | -3.61 $\pm$ 2.15   | 0.606   |
|                           | Female | -4.30 $\pm$ 1.64  |         | -3.02 $\pm$ 3.84   |         |
| UL-B                      | Male   | 3.86 $\pm$ 1.27   | 0.278   | 4.27 $\pm$ 1.69    | 0.817   |
|                           | Female | 3.31 $\pm$ 1.44   |         | 4.06 $\pm$ 2.99    |         |
| LL-B                      | Male   | 2.55 $\pm$ 1.32   | 0.453   | 4.24 $\pm$ 2.66    | 0.823   |
|                           | Female | 2.95 $\pm$ 1.50   |         | 4.49 $\pm$ 3.29    |         |
| Nasal length              | Male   | 2.57 $\pm$ 0.16   | 0.000*  | 2.69 $\pm$ 0.27    | 0.002*  |
|                           | Female | 2.33 $\pm$ 0.17   |         | 2.39 $\pm$ 0.20    |         |
| Tot. facial convex angle  | Male   | 141.60 $\pm$ 5.30 | 0.222   | 139.53 $\pm$ 5.33  | 0.640   |
|                           | Female | 143.73 $\pm$ 3.95 |         | 138.67 $\pm$ 4.69  |         |
| Facial convex angle       | Male   | 168.80 $\pm$ 4.44 | 0.581   | 165.40 $\pm$ 6.56  | 0.830   |
|                           | Female | 169.60 $\pm$ 3.33 |         | 164.93 $\pm$ 5.19  |         |
| Angle of the lower third  | Male   | 108.00 $\pm$ 5.92 | 0.001*  | 115.20 $\pm$ 7.76  | 0.002*  |
|                           | Female | 100.20 $\pm$ 4.84 |         | 105.13 $\pm$ 8.48  |         |
| Nasofacial angle          | Male   | 34.33 $\pm$ 2.66  | 0.001*  | 33.47 $\pm$ 3.72   | 0.629   |
|                           | Female | 31.13 $\pm$ 1.81  |         | 33.40 $\pm$ 2.23   |         |
| Nasolabial angle          | Male   | 103.47 $\pm$ 7.02 | 0.506   | 105.13 $\pm$ 12.70 | 0.604   |
|                           | Female | 105.27 $\pm$ 7.61 |         | 103.93 $\pm$ 13.54 |         |
| Mentolabial angle         | Male   | 137.47 $\pm$ 8.68 | 0.824   | 138.53 $\pm$ 10.33 | 0.290   |
|                           | Female | 136.73 $\pm$ 9.18 |         | 142.27 $\pm$ 10.29 |         |
| Total vertical proportion | Male   | 0.92 $\pm$ 0.09   | 0.032*  | 0.96 $\pm$ 0.08    | 0.019*  |
|                           | Female | 0.98 $\pm$ 0.05   |         | 1.05 $\pm$ 0.11    |         |
| Inferior third position   | Male   | 0.48 $\pm$ 0.05   | 1.000   | 0.48 $\pm$ 0.05    | 0.247   |
|                           | Female | 0.48 $\pm$ 0.05   |         | 0.46 $\pm$ 0.06    |         |
| Nasal height/length prop. | Male   | 0.78 $\pm$ 0.10   | 0.001#  | 0.72 $\pm$ 0.07    | 0.636   |
|                           | Female | 0.69 $\pm$ 0.05   |         | 0.71 $\pm$ 0.10    |         |
| Lip/chin prop.            | Male   | 1.35 $\pm$ 0.19   | 0.633   | 1.68 $\pm$ 0.38    | 0.073   |
|                           | Female | 1.34 $\pm$ 0.18   |         | 1.47 $\pm$ 0.22    |         |

\* Statistical significance (p &lt; 0.05) using Student's parametric t test;

# Statistical significance (p &lt; 0.05) using Mann-Whitney non-parametric test.

cephalometric radiographs were used for this purpose. Standardized photographs have currently gained significant importance both clinically and in research, mainly because they reproduce the soft tissues in detail.<sup>7,8,10,13,19</sup>

When examining the error of the method, significant differences were found in three out of the 19 variables analyzed, which can be interpreted as having used a very reliable method. The measures angle of the lower third of the face, nasolabial angle and lip-chin proportion showed significant errors. Thus, due the difficulty of reproducibility and/or precision of these variables, they should be clinically interpreted with caution.

In other articles, references have been made to the difficulty of measuring the angle of the lower third (Sn-Me' and Me'-C) and lip-chin proportion (Sn-Gn' and Gn'-C) due to the fact that both of them have the cervical point as reference, a point that is considered difficult to locate.<sup>10,19</sup> The accumulation of adipose tissue in the neck is cited as a factor that hinders measurement of the angle of the lower third of the face.<sup>13</sup> Reche et al<sup>19</sup> also point out the difficulty of measuring the nasolabial angle.

In this study, all linear measurements for the positioning of the lower lip in relation to the reference lines were statistically different between the pleasant and unpleasant groups. With regard to the distance of the lower lip to the S line, the pleasant group presented a profile with slight lip retrusion (mean -0.57 mm), which agrees with the findings of Carvalho<sup>20</sup>. Consequently, this study disagrees with the findings of Almeida et al<sup>12</sup> who claim that, in both sexes and regardless of race, faces with lips touching the S line or with a slight protrusion are considered as pleasant. In recent research, Nomura et al<sup>15</sup> investigated the preferences of evaluators of different ethnic groups assessing the positioning of the lips, and concluded that the African group of evaluators selected as pleasant those profiles with an average of -2.13 mm for the E line, a value that is very close to -2.02 mm obtained in this study.

The distance Pn-H also differs in the comparison between groups, and clinically expresses the amount of the nose that affects the profile. In other words, it represents the relationship between the nose, the upper lip and the chin, all of which are three important structures considered in the definition of a profile. It is worth noting that nasal length showed no significant difference between the profiles considered pleasant

and unpleasant. For this reason, it can be deduced that the most important is not the size of the nose itself, but its relationship with other facial structures.

In the present study, the measures that assessed the influence of facial convexity over pleasantness presented significant differences between the pleasant and unpleasant groups. This difference was observed in both total facial convexity angle and angle of facial convexity and is in disagreement with Trevisan and Gil<sup>8</sup> who found no significant differences in these variables between groups. However, these authors assessed patients with normal occlusion, whereas in this study, patient occlusion was not used as a criterion for inclusion or exclusion.

Data from this study corroborate the findings of a recent publication<sup>21</sup> which found a strong association between facial profile esthetics and facial convexity angles, and deduced that profiles of which angle is increased or reduced are considered less esthetically pleasant. The total facial convexity angle assesses how the nose contributes to face convexity.<sup>7</sup> In this study, the pleasant profiles mean of 142.37° (or 37.33° if we consider that some authors use the total value subtracted by 180°) agreed with the average of 38.93° found by Reche et al.<sup>19</sup> The facial convexity angle determines the harmony of the face in the middle and lower thirds.<sup>19</sup> In this study, the mean value for this angle was 169.2° (or 10.8°) in the pleasant group, a value that is very close to the average of 12° found among pleasant profiles investigated by Almeida et al.<sup>12</sup>

The angle of the lower third of the face assesses the protrusion of the chin in relation to the middle third of the face.<sup>21</sup> It is of great importance in facial esthetics, and it appears, in another research<sup>7</sup> as the third reason given by evaluators justifying an unpleasant profile. There is an agreement between the mean values obtained in this study and other similar studies,<sup>13,21</sup> however, Trevisan and Gil<sup>8</sup> found no significant differences for this variable between pleasant and unpleasant groups.

The total vertical proportion allows comparison between the height of the middle and lower thirds of the face, being the harmony and balance of the facial profile associated with a similar length of thirds.<sup>13</sup> In our sample, the mean value for the pleasant profiles was 0.95, very close to that obtained in other studies.<sup>13,21</sup> With regard to the lip-chin proportion, similar findings have been reported in the literature,<sup>8</sup> but with male patients, only.

In assessing sexual dimorphism, differences were found for the length of the nose, nasofacial angle, angle of the lower third of the face and the total vertical and nasal height/length proportions. Sex differences in the linear measure of nasal length are expected, since males are, in a homogeneous way, larger than females in nearly every physical aspect.<sup>22</sup> In a previous study, Reis et al<sup>13</sup> observed differences for the variables angle of lower third face and total vertical proportion. Other authors,<sup>9,23</sup> as well as in our study, did not find dimorphism regarding the position of the lips in relation to the reference lines.

In addition to the factors evaluated in this study, several others have an important influence over facial

attractiveness and have already been referred to in the literature, namely: color of teeth, hair,<sup>24</sup> lips, skin,<sup>7,24</sup> nose, chin, jaws and eyes.<sup>7</sup>

## CONCLUSION

The anteroposterior position of the lower lip, the amount of the nose that affects the profile, the facial convexity and total vertical and lip-chin proportions seem to influence the pleasantness of facial profile. Sexual dimorphism was identified in the linear measure of nasal length, nasofacial angle, angle of the lower third of the face and the total vertical and nasal length/height proportions.

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# Comparison of topical and infiltration anesthesia for orthodontic mini-implant placement

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**Objective:** To compare the acceptability and effectiveness of topical and infiltration anesthesia for placement of mini-implants used as temporary anchorage devices.

**Methods:** The sample comprised 40 patients, 17 males and 23 females, whose mean age was 26 years old and who were all undergoing orthodontic treatment and in need for anchorage reinforcement. Mini-implants were bilaterally placed in the maxilla of all individuals, with infiltration anesthesia on one side and topical anesthesia on the other. These 40 patients completed two questionnaires, one before and another after mini-implant placement and pain was measured through a visual analog scale (VAS). The data collected were analyzed using descriptive statistics and the measurements of pain were compared by means of the non-parametric test of Mann-Whitney.

**Results:** It was found that 60% of patients felt more comfortable with the use of topical anesthesia for mini-implant placement; 72.5% of patients described the occurrence of pressure during placement of the anchorage device as the most unpleasant sensation of the entire process; 62.5% of patients felt more pain with the use of topical anesthesia.

**Conclusion:** It was concluded that patients had less pain with the use of infiltration anesthesia, and also preferred this type of anesthetic.

**Keywords:** Anesthetics. Orthodontics. Dental implants. Orthodontic anchorage procedures.

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## INTRODUCTION

According to Newton's third law, every action has a reaction of equal magnitude and towards its opposite direction. Therefore, when a force is applied with the purpose of achieving orthodontic movement, the teeth used as support (anchorage) will have a reaction with the same intensity towards the opposite direction, which, in most cases, may generate undesirable effects.

In order to avoid such undesirable effects in orthodontic mechanics, the clinician should carefully plan the anchorage to be employed during treatment. However, some types of anchorage directly depend on patient's compliance, which may compromise the final results.

With a view to solving the issues related to anchorage, dentists have had the possibility of using devices that enable skeletal support for tooth movement.

Mini-implants and mini-plates are among the skeletal anchorage devices most commonly used for orthodontic mechanics. The use of mini-plates and mini-implants enable dental movement to be safely performed, many times, without undesirable side effects, at the vertical, transverse, and anterior-posterior planes.<sup>1</sup>

The orthodontic loads of continue and unidirectional nature and of low magnitude are not capable of generating osteolytic activity on the bone interface of the implant.<sup>2,3</sup>

Assessment of patients' acceptance factors regarding the use of mini-implants during orthodontic treatment reveals that the need for infiltrative anesthesia is one of the factors that patients reject the most.<sup>4</sup> Additionally, the association with osseointegrated implants is another factor that contributes to increase the rejection and fear of patients with regard to the use of mini-implants. Several topical anesthetics are available to be used before minor dental procedures are performed and they are largely accepted by the patients.

The ideal topical anesthetic would promote complete anesthesia, with fast action onset and without any side effects. The agents currently available, however, are only close to this ideal.<sup>5</sup>

The possibility of placing mini-implants with the use of topical anesthetic only, has already been suggested in the literature.<sup>4,6,7</sup> Some authors have reported that mini-implants could be successfully and comfortably placed with the use of topical anesthetic, only.<sup>8</sup> Two types of topical anesthetics used for mini-implant

placement have been compared, and one of them showed highly satisfactory results.<sup>9</sup> Additionally, it has been proved that 90% of patients undergoing mini-implant placement with the aid of topical anesthesia only, would accept to have mini-implants replaced, if necessary. In this study, 40% of patients reported not having felt any type of pain during placement of the mini-implant, while 20% reported mild pain.<sup>10,11</sup>

However, no study has been conducted to compare the acceptability and effectiveness of infiltrative and topical anesthetics. Thus, the aim of this study was to compare, by means of pre and post-operative questionnaires answered by the patients, the acceptability and discomfort of infiltrative and topical anesthetics used for placement of mini-implants as skeletal anchorage in Orthodontics.

## MATERIAL AND METHODS

### Sample

This study was approved by the Ingá School of Dentistry Institutional Review Board. Sample calculation was based on alpha error of 5% and beta error of 20%, so as to reach a power test of 80% in order to detect a significant difference of 1.00 cm in VAS scale, with a standard deviation of 1.5, resulting in 36 subjects required for each group.

The study sample comprised 40 patients, 17 males and 23 females, with mean age of 26 years old (not younger than 14, not older than 45 years old). All patients underwent orthodontic treatment and needed bilateral absolute anchorage through mini-implants in the maxilla.

This was a prospective study of which patients were treated in the Orthodontic Clinics of the Masters Course of the Ingá School of Dentistry, and required the placement of bilateral maxillary mini-implants while the study was being carried out, until the number of 40 subjects was obtained.

All patients had the mini-implants placed at the same appointment. The anesthetic was used alternately, that is, the topical anesthetic was applied on one side, while the infiltrative anesthetic was used on the other side. The anesthesia was applied by one examiner who had been previously trained by a Professor of the Masters Course in Orthodontics who, in turn, has extensive expertise in the mini-implant placement either with infiltrative or topical anesthesia.

Two questionnaires (one before and one after mini-implant placement) were given to each patient in order to compare the efficiency of each anesthetic.

### Anesthetics

Patients underwent two different anesthetic procedures for mini-implant placement:

- » Infiltrative – lidocaine hydrochloride+ epinephrine 1:100,000 (Alphacaine 100, DFL Commerce and Industry, Jacarepaguá-RJ, Brazil) applied where the mini-implant was placed, with the aid of a 0.30 x 21 mm gingival needle (Terumo) in the mucosa area, only, with 1/5 of the tube being injected. Mini-implant placement was performed 2 minutes after the infiltrative anesthesia was applied.
- » Topical: on the opposite side, topical anesthetic gel with 20% lidocaine (Relva Dermatological Pharmacy, Campo Grande-MS, Brazil) was applied for 7 minutes on the area of the mucosa that received the mini-implant. If the patient reported great pain during mini-implant placement with topical anesthetic, the procedure would be interrupted and the infiltrative anesthetic would be used.

### Mini-implants

Self-drilling mini-implants 6 mm in length and 1.5 mm in diameter (Conexão, São Paulo, Brazil) were used in this study. To place the implants, a surgical kit with hand key (Conexão, São Paulo, Brazil) was used.

### Mini-implant placement

All patients included in this study were submitted to the following protocol:

- » The patient answered the pre-operative questionnaire.
- » Drying with air jet and relative isolation was performed with cotton rolls to move the lip away from the area where the mini-implant would be placed under topical anesthetic.
- » Topical anesthesia with 20% lidocaine gel was applied on a cotton pellet placed onto the mucosa where the mini-implant would be placed. The gel had to be kept on the mucosa for 7 minutes.
- » Removal of excess gel with the aid of a gauze.

- » Mini-implant placement.
- » On the opposite side, infiltrative anesthesia with Alphacaine 100 (lidocaine hydrochloride+ epinephrine 1:100,000) was applied in the area where the mini-implant would be placed.
- » Mini-implant placement 2 minutes after anesthesia.
- » The patient answered the post-operative questionnaire.

The type of anesthesia that was applied first should be alternated for every other patient. All mini-implants were placed without the need for previous perforation.

### Questionnaires

The patients included in the sample were submitted to questionnaires comprised of objective questions before and after mini-implant placement. (Questionnaires are available at <http://dpjo.dentalpresspub.com/editions/v19n2/076-083/>).

The visual analogue scale (VAS),<sup>12</sup> which is largely used for pain quantification, was employed in question number 4 of the post-operative questionnaire.

### Statistical analysis

A descriptive statistical analysis was performed. The comparison of the VAS results for topical and infiltrative anesthetics was performed by means of the Mann-Whitney non-parametric test.

To evaluate the sexual dimorphism of the responses of VAS, the Mann-Whitney non-parametric test was applied.

All tests were performed with the aid of Statistica software (Statistica for Windows, version 7.0, Statsoft, 2005). The level of significance was set at  $P < 0.05$ .

## RESULTS

### Pre-operative results

Out of the 40 patients comprising the sample, 65% answered that they calmly accepted the proposal for mini-implant placement (Fig 1). 67.5% of patients reported that their main concern about the procedure was with regards to pain (Fig 2).

When asked about the most worrying procedure, the responses “Mini-implant placement” and “Infiltrative anesthesia (needle)” were the most frequent ones with 37.5% and 35% respectively (Fig 3).

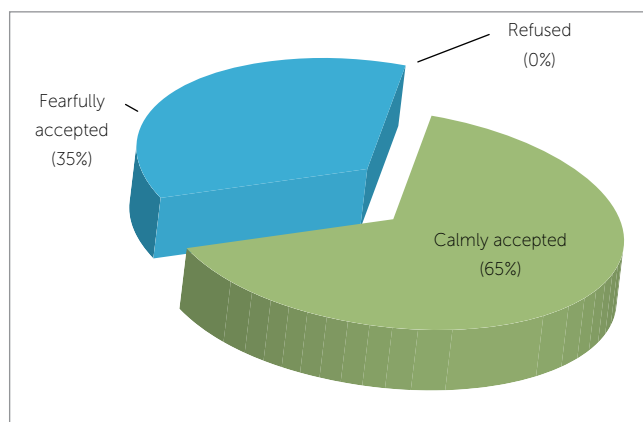


**Figure 1** - Answers to question number one of the pre-operative questionnaire: "When your orthodontist proposed mini-implant installation, how did you react?"

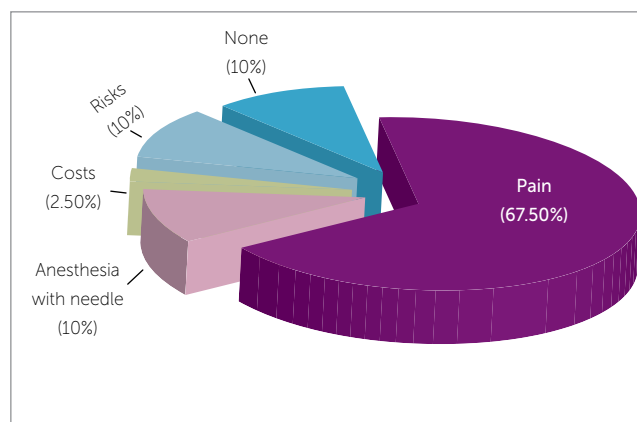


**Figure 2** - Answers to question number two of the pre-operative questionnaire: "After the dentist proposed mini-implant installation, which was your main doubt regarding the procedure?"

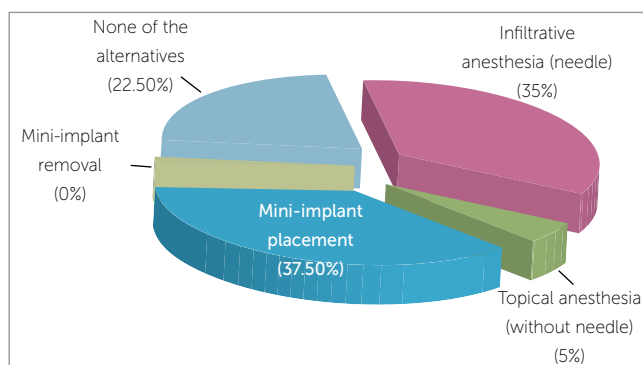


**Figure 3** - Answers to question number three of the pre-operative questionnaire: "Which of these procedures make you more fearful about installing the mini-implant?"

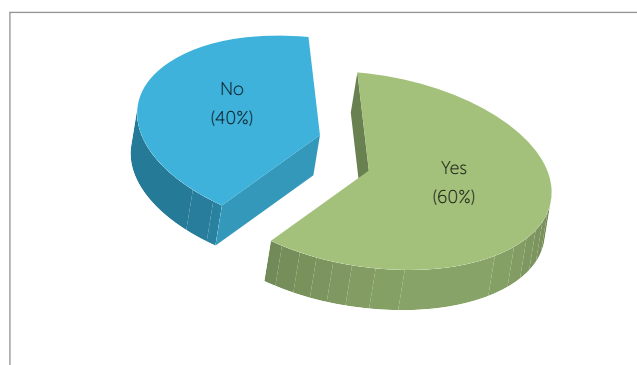


**Figure 4** - Answers to question number four of the pre-operative questionnaire: "Does the fact of using the topical anesthesia (without needle) make you more comfortable regarding the mini-implant installation?"

Sixty percent (60%) of patients claimed to feel more comfortable towards having mini-implants placed with topical anesthesia (Fig 4).

### Post-operative results

Twenty-nine patients (72.5%) reported that pressure during mini-implant placement was the most unpleasant sensation they felt during treatment (Fig 5). When asked whether they felt pain at any moment during mini-implant placement, 65% of patients answered

affirmatively, while 35% claimed that they did not feel any pain (Fig 6). As for the type of anesthesia that caused the most severe pain, 62.5% of patients answered that pain was worse under topical anesthesia (Fig 7).

According to the responses obtained, the anesthetic of choice of the majority of patients was the infiltrative anesthetic (23 patients), while 13 patients preferred the topical anesthetic and 4 patients reported they did not have any preference regarding the anesthetic used (Fig 8).

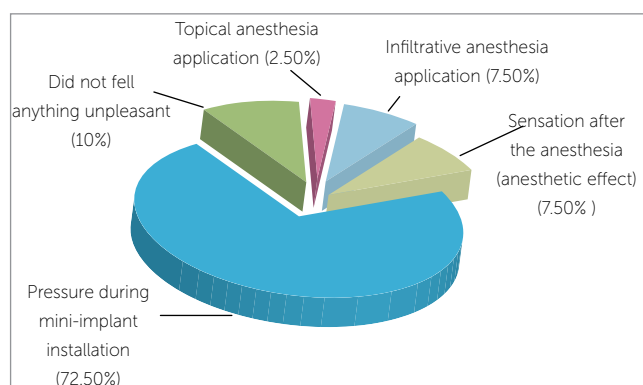


**Figure 5** - Answers to question number one of the post-operative questionnaire: "Which was the most unpleasant sensation related to mini-implant installation?"

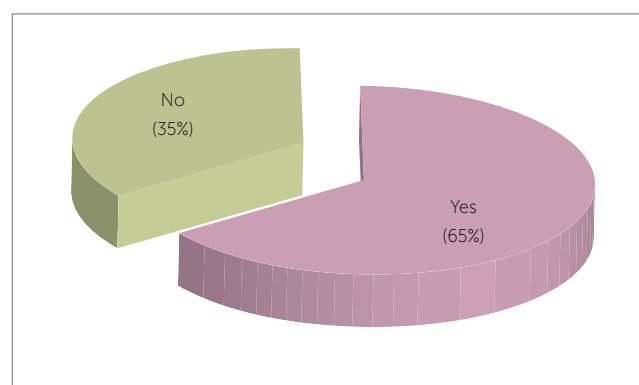


**Figure 6** - Answers to question number two of the post-operative questionnaire: "Did you feel pain at any moment of the mini-implant installation?"

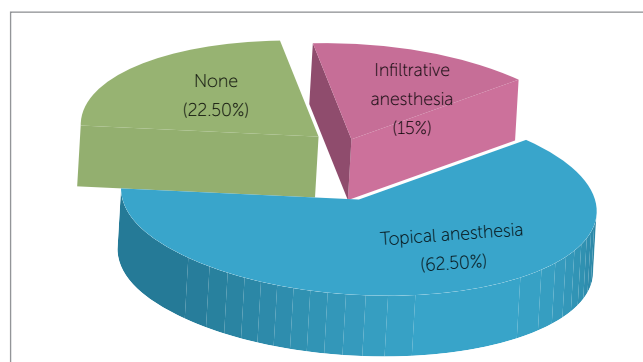


**Figure 7** - Answers to question number three of the post-operative questionnaire: "With which type of anesthesia did you feel more painful sensation?"

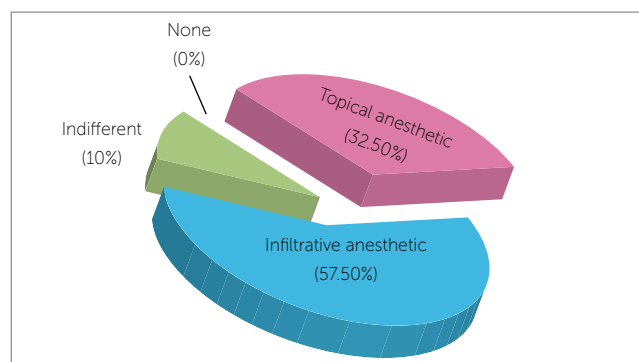


**Figure 8** - Answers to question number five of the post-operative questionnaire: "By comparing topical and infiltrative anesthesia, which type did you prefer?"

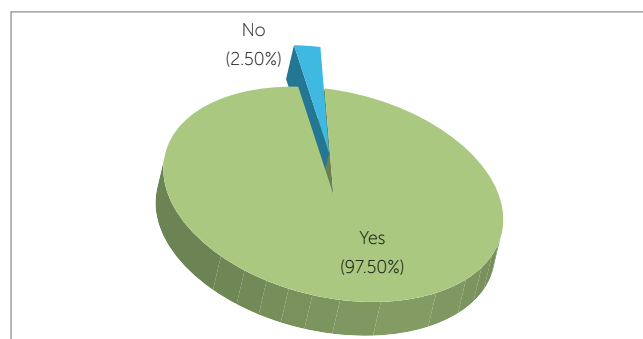


**Figure 9** - Answers to question number six of the post-operative questionnaire: "If necessary, would you be submitted to mini-implant installation again?"

Only one patient claimed to refuse having mini-implant replaced, if necessary (Fig 9).

Mean values of pain were obtained by assessment of the visual analogue scale used in question 4 of the post-operative questionnaire. The infiltrative anesthetic obtained a mean value of 0.3125, while the topical anesthetic obtained a mean value of 3.0875. These data were compared through the Mann-Whitney non-parametric test, with statistically significant differences. As a result, mini-implants placed with topical

anesthetic caused significantly more pain than those placed with infiltrative anesthesia, as shown by the VAS scale (Table 1). When the sample was divided according to sex, the mean values obtained were 0.2647 with the infiltrative anesthesia and 3.6764 with the topical anesthesia in males; whereas females had mean values of 0.3478 with the infiltrative anesthesia and 2.6521 with the topical anesthesia. These data were also submitted to the Mann-Whitney non-parametric test, without statistically significant differences (Table 2).

**Table 1** - Comparison of VAS results through the Mann-Whitney non-parametric test.

| Variable | Infiltrative anesthesia<br>(n = 40) | Topical anesthesia<br>(n = 40) | p      |
|----------|-------------------------------------|--------------------------------|--------|
|          | Mean $\pm$ SD                       | Mean $\pm$ SD                  |        |
| VAS      | 0.31 $\pm$ 0.64                     | 3.08 $\pm$ 2.54                | 0.000* |

\* Statistically significant for  $P < 0.05$ .

**Table 2** - Sexual dimorphism assessment by comparison of VAS results through the Mann-Whitney non-parametric test.

| Variable     | Male<br>(n = 17) | Female<br>(n = 23) | p     |
|--------------|------------------|--------------------|-------|
|              | Mean $\pm$ SD    | Mean $\pm$ SD      |       |
| Infiltrative | 0.26 $\pm$ 0.66  | 0.34 $\pm$ 0.64    | 0.671 |
| Topical      | 3.67 $\pm$ 2.29  | 2.65 $\pm$ 2.67    | 0.112 |

## DISCUSSION

### Discussion of the method

Many authors have suggested the possibility of using topical anesthetic for mini-implant placement with a view to obtaining the analgesia required for complete insertion of the anchorage device without blocking the sensibility of the surrounding structures, thus, reducing the chances of damages if the mini-implants reaches these structures.<sup>4,6,11</sup> In the present study, the use of topical gel anesthetic (20% lidocaine)<sup>10,11</sup> was chosen because it reaches good levels of analgesia, can be easily handled and does not cause tissue damage, as previously reported by the literature. The application protocol used in this study also followed the recommendations of a previous study,<sup>10</sup> that is, the gel was kept in contact with the mucosa for 7 minutes under relative isolation and care so that it did not surpass the area of interest.

With regard to the infiltrative anesthetic, lidocaine hydrochloride + epinephrine 1:100,000 (Alphacaine 100®) was used due to the fact that it is largely employed in Dentistry with low toxicity rates and enough anesthetic effect. The amount of anesthetic used was of 1/5 of the tube, injected in the area of the mucosa where the mini-implant would be placed so as to allow a satisfactory anesthesia and prevent the surrounding structures from being anesthetized, as suggested by the literature.<sup>13,14</sup>

Self-drilling mini-implants (Conexão®), 6 mm in length and 1.5 in diameter were used with the aid of a surgical kit (Conexão®). The sequence of insertion was carried out in turns: half of times infiltrative anesthesia was the first procedure, while half of times topical anesthesia was applied first. The sides of insertion were also alternated in order to avoid any potential influences over patients' responses.

The use of topical anesthetic is very common before infiltrative anesthesia so as to decrease the discomfort in the application of the latter. However, such procedure was not carried out in this study. Pain was assessed while the mini-implant was being placed and not during anesthesia application, whether topical or infiltrative.

The mini-implants were bilaterally placed in the area between pre-molars and molars, on both sides of the same patient, so that the insertion area would not influence patient's pain sensitivity. The alternate order of use of the anesthetics for mini-implant placement also enabled the differences in sensitivity of both types of anesthetics to follow a single pattern of influence over the results.

Other factor that could have influenced the results was the anatomical differences of each patient, as they could alter pain threshold. Notwithstanding, because mini-implants were placed with both anesthetics in the same patient, this factor was practically annulled.

The visual analogue scale was used to record pain rates. It was chosen due to its easy clinical applicability and great power of pain measurement.<sup>12</sup>

### Discussion of results

In the present study, the acceptability of mini-implant placement was of 100% for all cases. However, 35% of patients answered they accepted with fear, while in another study 90% of patients answered "I immediately accepted because I totally trust my orthodontist". Nevertheless, this latter study comprised a considerably smaller sample (10 patients) and did not aim at evaluating different types of anesthesia, which could have influenced the data obtained.<sup>4</sup>

Infiltrative anesthesia was reported by 14 subjects as one of the most fearful procedures, followed by the fear of mini-implant placement, chosen by 15 patients. Sixty percent of patients reported that the use of topical anesthetic made them feel more comfortable with regard to the procedure, which proves that infiltrative anesthesia applied with the aid of a needle causes certain discomfort in a considerably number of patients,<sup>15</sup> leading some of them to refuse being submitted to procedures of anchorage device placement.

After mini-implant placement, patients reported that the most unpleasant sensation they felt during the entire procedure was the pressure during placement, which was also observed by another study,<sup>4</sup> but disagrees with what was found by Santos et al<sup>11</sup> who reported that patients did not feel anything unpleasant.

Twenty-five patients pointed out that topical anesthesia caused the most painful sensation, proving that infiltrative anesthesia resulted in greater anesthetic effect for the patients of the sample.

Mini-implant placement could not be completed in three patients who received topical anesthetic. These patients reported severe pain, and for this reason, the procedure was discontinued, following the methods of this study. Later on, these same patients underwent infiltrative anesthesia and in two of them, the mini-implants were placed under infiltrative anesthesia. The other case was initiated by topical anesthetic. In the study conducted by Reznik et al,<sup>9</sup> who compared two types of topical anesthetics, the failure rate (impossibility of finishing the installation under topical anesthesia) was of 71% (12 cases) when 20% benzocaine was used, whereas there was no failure when 20% lidocaine + 4% tetracaine + 2% phenylephrine anesthetic was used.

When patients were asked whether they would accept to have mini-implants replaced, 97.5% (39 patients) gave affirmative answers, while in the study conducted by Santos et al,<sup>11</sup> 10% of patients would not accept it, and according to Brandão and Mucha,<sup>4</sup> 10% of patients would not recommend this procedure to other patients.

The analysis of the data obtained with the visual analogue scale demonstrated that the mean values exhibited by the infiltrative anesthesia were minimum and significantly lower than those of the topical anesthesia (Table 1). Moreover, it could be observed that the discrepancy of pain values between both types of anesthetic was statistically significant. However, 42.5% of patients did not choose the infiltrative

anesthesia as their procedure of choice (Fig 8), which demonstrates the rejection of most patients in regard to anesthetic procedures performed with the aid of needles.

The results of the visual analogue scale divided by sex demonstrated lower mean values for females when topical anesthetic was used. However, when the Mann-Whitney non-parametric test was applied to verify sexual dimorphism, the values did not prove to be statistically significant (Table 2).

### Clinical considerations

Failure was reported in three cases of mini-implant placement under topical anesthesia. Following the methods established for this study, infiltrative anesthesia was then applied and the anchorage device was installed. However, it was clear that, in all three cases of failure, the patients exhibited great anxiety while the procedure was being carried out, and after infiltrative anesthesia, they did not report any pain. The present study demonstrates that patients reported greater sensitivity in cases of mini-implant placement under topical anesthesia, without, however, reporting any discomfort during the anesthetic application. On the other hand, in cases of mini-implant placement carried out under infiltrative anesthesia, patients reported certain degree of discomfort during anesthetic application, but significant comfort during mini-implant placement, which must be assessed by both the dentist and the patient in the decision for which type of anesthetic should be employed.

Mini-implant placement under topical anesthesia seems to be a viable option in cases in which patients refuse to undergo infiltrative anesthesia in fear of the needle, especially in less anxious patients.

### CONCLUSION

Based on the results of the present study, it is reasonable to conclude that:

- » The use of topical anesthetic results in more comfort to patients undergoing mini-implant placement procedures;
- » Patients considered pressure during mini-implant placement as the most unpleasant sensation;
- » Pain sensitivity of mini-implant placement with topical anesthetic was significantly greater than that of infiltrative anesthesia;
- » Most patients submitted to mini-implant placement preferred the procedure under infiltrative anesthesia.

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# Evaluation of a photographic method to measure dental angulation

Jordana Rodrigues Amorim<sup>1</sup>, Diogo de Vasconcelos Macedo<sup>2</sup>, David Normando<sup>3</sup>

**Objective:** To analyze the reliability and reproducibility of a simplified method for analysis of dental angulation using digital photos of plaster dental casts.

**Methods:** Digital and standardized photographs of plaster casts were performed and posteriorly imported to an angle reading graphic program in order to have measurements obtained. Such procedures were repeated to evaluate the random error and to analyze reproducibility through intraclass correlation. The sample consisted of 12 individuals (six male and six female) with full permanent dentition orthodontically untreated. The analyses were bilaterally carried out, and generated 24 measurements.

**Results:** The random error showed variation of 0.77 to 2.55 degrees for teeth angulation. The statistical analysis revealed that the method presents excellent reproducibility ( $p < 0.0001$ ) for all teeth, except for the upper premolars. In spite of that, it is still considered statistically significant ( $p < 0.001$ ).

**Conclusion:** The proposed method presents enough reliability that justifies its use in the development of scientific research as well as in clinical practice.

**Keywords:** Dental crown. Dental photography. Evaluation.

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## INTRODUCTION

Knowledge on mesiodistal angulation of dental crowns became more prominent after the study described by Andrews in 1972, regarding the “Six keys for an optimal occlusion,”<sup>1</sup> among which the second key states that a tooth correctly angulated in the arch is one of the criteria used to achieve functional occlusion. In this study, the angulations of the dental crowns were determined by measuring the angle formed between the buccal axis of the clinical crown with a line perpendicular to the occlusal plane, on the specimens previously cut out in the center of the clinical crown, using a plastic protractor.

Although undoubtedly important, Andrews’ work was applied to only one sample of American individuals and on the reproduction of his methods, it was observed difficulty regarding the accuracy on the positioning of rulers and protractor, thus, generating doubts and high variance of results.<sup>3</sup> Moreover, the cut out of specimens mentioned in that method proves to be inconvenient due to the amount of work and clinical time that is spent, in addition to the discard of orthodontic models.

From the values obtained by Andrews’ study, the means of angulations for each dental crown were established. It is possible, however, to assert that dental angulations do not always follow a constant pattern, so that there might be variability on angular values according to the individual characteristics of each patient, considering different cases of malocclusion. Thus, studies that engage in learning and evaluating the ideal mesiodistal positioning become undoubtedly relevant.

A device projected specifically to measure the angulations and inclinations of the dental crowns in plaster casts has been recently presented.<sup>3</sup> With the development of this device, which consists of an alteration in the original methods of Andrews, it was possible to establish mean values of angulation and inclinations of dental crowns for Brazilian individuals with normal occlusion. However, this methods involve a device that is not available in the market, thus, requiring customized production.

Computed tomography (CT) can be useful to assess dental inclinations and angulations,<sup>4</sup> allowing great progress to researches involving tooth positioning and, also, to the individualization of orthodontic treatment. However, since this method is relatively new and still needs further studies that prove

its efficiency and reliability, it must be used with reservations. Furthermore, the high costs of CT scans and the risks inherent to its radiation are some of the disadvantages of this technique.

Therefore, there is a need for methods of simple application that allow the orthodontist to identify and quantify, in a reliable manner, the mesiodistal positioning of the dental crowns, as well as the natural compensation existing in many patients with malocclusion. Thus, the objective of this study is to evaluate the reliability of a photographic method previously described, which, however, had been limited to analyzing canine angulation.<sup>5,6</sup> In the present study, this method was used to quickly and simply measure the angulations of all teeth anteriorly positioned in relation to the permanent first molar.

## MATERIAL AND METHODS

This study was approved by the Institutional Review Board of the Institute of Health Sciences of the Federal University of Pará (ICS/UFPA), under protocol number 154-09 and by the National Committee of Ethics in Research (CONEP), under number 25000.066559/2010-11, report number 462/2010.

The sample comprised 12 individuals with permanent dentition and with natural normal occlusion, of which six were males and six females, with mean age of 13.7 years old. The angulations of the first molars, premolars, canines and incisors were bilaterally obtained, in both arches of the initial casts of the selected individuals, thus generating 24 measurements for each tooth, according to the method previously described.<sup>5,6</sup>

In this method,<sup>5,6</sup> the specimens were positioned on a glass plate, at a distance of 20 cm from the photographic lens. A black device with a mark in the center was placed in the background of each specimen, and used as reference to centralize the group of teeth that would be examined. The camera lens was placed against a red wax plate in order to optimize the direction of the lens (Fig 1). Five photographs were taken per arch: two lateral — one in each hemi arch — centralizing the second premolar to the mark in the background, to measure the angulation of the first molar and the premolars; two diagonal, having the line between the canine and the lateral as the central point for the bilateral measurement of these teeth; and one frontal for the measurement of the central incisors (Fig 2).

Ten photographs were taken per individual, totalizing 120 photographs which were then imported to a computer software (Paint Microsoft®, Microsoft Corporation, Redmond, USA) in order to have the occlusal plane drawn. Posteriorly, the images were imported to a graphical computer software (Image Tool® — [www.imagetool.com](http://www.imagetool.com), Image Tool Software, USA), in order to measure teeth angulation.

In both lateral and diagonal photographs, the line corresponding to the occlusal plane was traced from the incisal surface of the central incisors to the mesiobuccal cusp of the permanent first molar. On the frontal photographs, this line was traced touching the tip of the cusp of the canines, as proposed in previously published researches.<sup>5,6</sup>

Posteriorly, through Image Tool®, the long axis of the canine's clinical crown was traced and, from the intersection of these two lines (occlusal plane and long axis), the value of angulation of the clinical crown of the plaster cast was obtained (Fig 3). As for random error analysis, the hemi-arches of the initial plaster molds of all patients were photographed again after 7 days and all the aforementioned steps were repeated until new measurements of the dental angulation were obtained. The random error was calculated according to Dahlberg's formula. The analysis of reproducibility was performed by the test of intraclass correlation, both with a level of reliability of 95%.

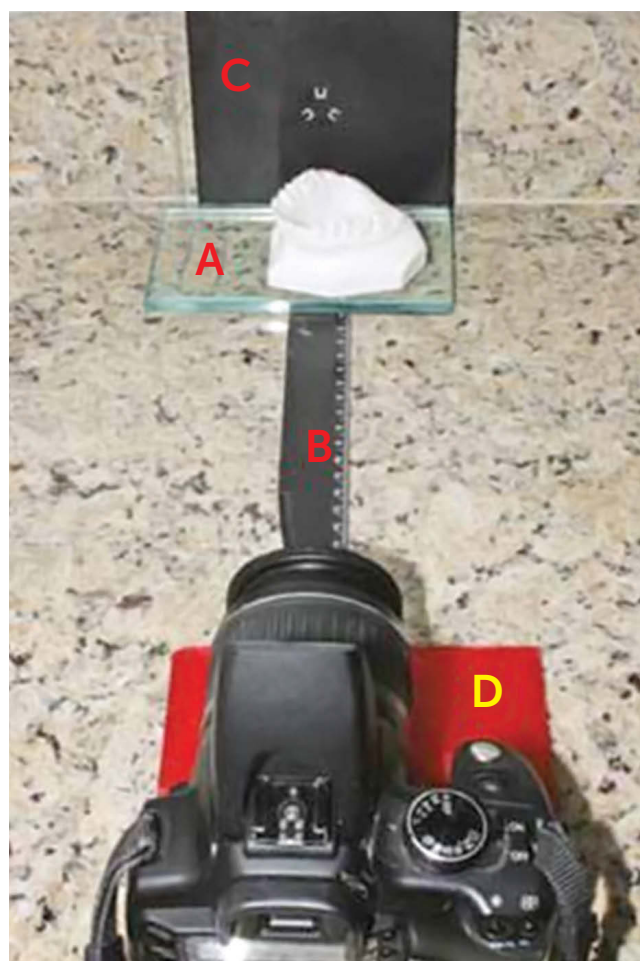


**Figure 1** - Method used for standardization of the photographic takes of the plaster molds: A= 10-mm-thick glass plate; B= 20-cm millimeter ruler; C= black plastic plate with mark indicating the center of the object (the back of a CD-ROM case), D= red wax plate.



**Figure 2** - Plaster molds used in the sampling.

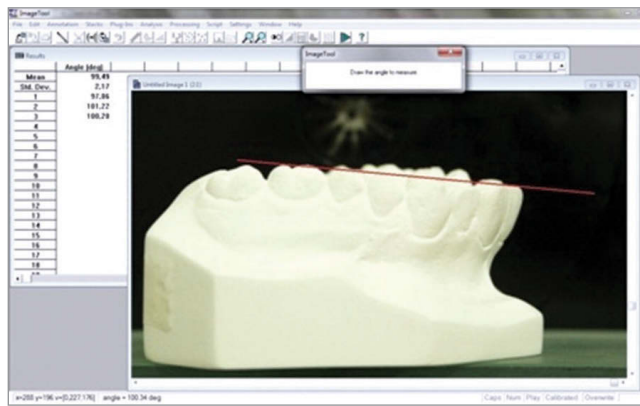


**Figure 3** - Photograph of the plaster mold exported to the graphic software used to obtain the measurements of the dental angulations.

## RESULTS

The results revealed a minor random error, less than one degree, except for the upper molars (2.55 degrees). With regard to the analysis of reproducibility (intraclass correlation), the statistical analysis revealed an excellent reproducibility of the method ( $p < 0.0001$ ), except for the upper premolars, of which reproducibility was classified as being from regular to good ( $r = 0.65$  and  $0.71$ ,  $p < 0.001$ ) (Table 1). The results also revealed that the difference of the angulation means was relatively minor and less than one degree, except for the upper first molars (2.29 degrees) (Table 2).

**Table 1** - Upper and lower teeth – Random error, method reproducibility (intraclass correlation) and analysis of normality of the distribution of values.

| Tooth | Random error | Intraclass correlation (r) | p value      | Reproducibility |
|-------|--------------|----------------------------|--------------|-----------------|
| U6    | 2.55         | 0.76                       | $p < 0.0001$ | Excellent       |
| U5    | 1.98         | 0.65                       | $p = 0.0003$ | Regular to good |
| U4    | 2.35         | 0.71                       | $p < 0.0001$ | Regular to good |
| U3    | 1.84         | 0.91                       | $p < 0.0001$ | Excellent       |
| U2    | 1.12         | 0.93                       | $p < 0.0001$ | Excellent       |
| U1    | 0.77         | 0.92                       | $p < 0.0001$ | Excellent       |
| L6    | 1.58         | 0.84                       | $p < 0.0001$ | Excellent       |
| L5    | 1.86         | 0.84                       | $p < 0.0001$ | Excellent       |
| L4    | 1.62         | 0.88                       | $p < 0.0001$ | Excellent       |
| L3    | 1.57         | 0.90                       | $p < 0.0001$ | Excellent       |
| L2    | 1.55         | 0.91                       | $p < 0.0001$ | Excellent       |
| L1    | 1.06         | 0.78                       | $p < 0.0001$ | Excellent       |

**Table 2** - Upper and lower teeth – Angulation means and difference means.

| Teeth | Mean – T <sub>1</sub> | Mean – T <sub>2</sub> | Difference means |
|-------|-----------------------|-----------------------|------------------|
| U6    | 89.69                 | 91.98                 | -2.29            |
| U5    | 90.02                 | 89.99                 | 0.03             |
| U4    | 89.48                 | 89.69                 | -0.22            |
| U3    | 92.46                 | 91.47                 | 0.98             |
| U2    | 100.2                 | 99.6                  | 0.6              |
| U1    | 96.47                 | 96.24                 | 0.23             |
| L6    | 95.56                 | 95.92                 | -0.36            |
| L5    | 92.82                 | 93.15                 | -0.33            |
| L4    | 88.61                 | 88.94                 | -0.325           |
| L3    | 94.57                 | 93.52                 | 1.06             |
| L2    | 91.44                 | 90.51                 | 0.94             |
| L1    | 89.93                 | 89.77                 | 0.16             |

## DISCUSSION

The degree of reliability of measurements taken in specimens has not yet been properly evaluated, perhaps because, originally, it is considered a direct method. However, the changes used in the present study showed that the method used to measure the angulations of dental crowns is greatly reproducible, presenting a random error equal to or less than 2.55 degrees, in addition to being very simple and avoiding the need for detrition of the specimens.

Some methods have been described in the literature for the evaluation of teeth angulation, similarly to the method proposed by Andrews, which uses measurements directly taken on the specimens through a plastic protractor,<sup>1</sup> and others that involve advanced technological resources, such as the use of computed tomography.<sup>4</sup> Other methods also describe the use of devices specially developed for this purpose.<sup>3,7,8</sup> It is natural, however, that each one of the described methods present inherent difficulties, such as certain imprecision on the positioning of the measuring tool,<sup>1</sup> cut out and discard of the plaster molds,<sup>1</sup> high costs,<sup>4</sup> radiation risks<sup>4</sup> and devices that are not available in the market and, for this reason, have to be customized.<sup>3,7,8</sup>

With the technological progress, modern computer software allow reliable analysis of images at low costs. Thus, for the present study, a computed graphical program capable of accurately reading the teeth angulations from the standardized digital photographs of the plaster molds was used.

The method proposed presents differences in relation to Andrews' original proposal. First, the occlusal plane, that, in this study, was represented by a line that connected the incisal surface of the incisors to the tip of the mesiobuccal cusp of the first molar and, on the frontal photographs, a line that touched the tip of the cusp of the canines. This plane is not always parallel to Andrews' plane, especially in cases of malocclusion.

The values found by Andrews and described as normal were very important factors for the development of the Straight-Wire technique, which aimed to individualize the appliance according to patient's orthodontic needs.<sup>2</sup> This pre-programmed appliance uses brackets individually built for each tooth: to these brackets is conferred the information about

the ideal mesiodistal and buccolingual position that each element must achieve by the end of the orthodontic treatment. However, the occlusal and skeletal characteristics of each patient are unique, which hinders the creation of a rigid protocol for the detailing of the cases. Since then, many orthodontists began to individualize brackets angulation according to their clinical experience, due to the morphological variations inherent to the dentofacial complex, being most of these modifications introduced without any scientific support.

What seems to be clinical evidence based on the experience of each professional, needs scientific evaluation that support or not the changes inserted on orthodontic appliances used with the objective of individualizing the cases. Methods of simple application, which allow the orthodontist to identify the presence of existing natural compensations, or even to reliably quantify them, would allow the clinician to extend the use of this concept in a scientifically adequate way.

The challenge of developing accessible methodological procedures is the main factor responsible for the lack of studies aimed at discovering the buccolingual and mesiodistal positioning of each dental element in the arch. Thus, a method that allows analysis of the dental angulation in a quick and simple way through materials easily available and software of free access represents a great resource to clinicians.

The method for analysis of the dental angulation described and tested in the present study had been previously used to compare the angulation of canines in individuals with Class I and III malocclusion,<sup>5</sup> as well as to analyze the correlation between the angulation of canines and the inclination of incisors.<sup>6</sup> In both studies, the random error and the systematic error were evaluated and yielded results based on which it can be concluded that the method is considered valid. However, both authors only applied and evaluated this method in anterior teeth and in lateral photographs. It is worth noting that no studies have been yet conducted to prove the reproducibility and reliability of the proposed method when applied to analyze the mesiodistal angulations of the crowns of all teeth anterior to the permanent first molar.

By using and testing the new method proposed in the present study, it is reasonable to conclude that the

suggested method presents excellent reproducibility ( $P < 0.0001$ ), agreeing with the results described by other authors,<sup>5,6</sup> except for the upper premolars that presented a reproducibility classified as being from regular to good ( $P < 0.001$ ), but yet statistically significant.

The lowest reproducibility found in the measurements performed on upper premolars possibly occurred due to the shorter length of the clinical crown of these teeth, since these teeth present a shorter cervico-occlusal distance the more posterior they are. Once premolars do not present reference lines on the buccal surfaces, as molars do, in addition to being shorter teeth, it is possible to find greater variance on the marking of the long axis of the crown and consequent distortion on the obtained results.

## CONCLUSION

Based on the analysis of the results of this study, it is reasonable to conclude that the method described herein presents enough reliability to justify its use both in clinical practice and as auxiliary means on the development of scientific research that focus on the evaluation of the angulations of dental crowns. Moreover, it presents excellent reproducibility, without any difference between the two measurements performed, and with random error relatively small, it achieves the initial proposal of reducing the time that is necessary to take the measurements. Furthermore, it is easy to be executed by the clinician and also allows the preservation of the plaster casts, important objects of orthodontic documentation of the patient.

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# Reliability of CBCT in the diagnosis of dental asymmetry

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**Objective:** The aim of this study was to validate a method used to assess dental asymmetry, in relation to the skeletal midline, by means of CBCT.

**Methods:** Ten patients who had CBCT scans taken were randomly selected for this study. Five different observers repeated 10 landmarks (x, y and z variables for each) and 12 linear measurements within 10 days. Measurements were taken in both arches to evaluate symmetry of first molars, canines and dental midline in relation to the skeletal midline. Intraclass correlation coefficient (ICC) was carried out to assess intra- and interobserver reliability for landmarks and distances. Average mean difference was also assessed to check measurement errors between observers.

**Results:** ICC landmarks was  $\geq 0.9$  for 27 (90%) and 25 (83%) variables for intra- and interobserver, respectively. ICC for distances was  $\geq 0.9$  for 7 (58%) and 5 (42%), respectively. All ICC landmarks for distances were  $>0.75$  for both intra- and interobserver. The mean difference between observers was  $\leq 0.6$  mm for all the distances.

**Conclusion:** The method used to assess dental asymmetry by means of CBCT is valid. Measurements of molars, canines and dental midline symmetry with the skeletal midline are reproducible and reliable when taken by means of CBCT and by different operators.

**Keywords:** Cone-beam computed tomography. Imaging. Three-dimensional diagnosis. Dental arch.

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

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## INTRODUCTION

Patients with malocclusion often present one or more characteristics related to asymmetry, for instance, Class II or III subdivision, dental midlines that are not coincident with each other, and/or dental midlines that are not coincident with the facial midline.<sup>1</sup> Proper orthodontic treatment planning requires a correct diagnosis. Dental arch rotation on the vertical axis, known as yaw, is often omitted in classifications and diagnosis. This important piece of information can determine the need for asymmetric mechanics or extractions to correct a dental midline shift or a unilateral Class II or III relationship, for example.<sup>2</sup>

Different methods can be used for diagnosis of patient's dental symmetry in relation to the skeletal midline (midsagittal plane). Burstone<sup>1</sup> has suggested, within a few limitations, the use of posteroanterior radiography to evaluate maxillary and mandibular discrepancies and the upper and lower dental midlines in relation to the skeletal midline. Another method suggests that the median raphe is the patient's skeletal midline.<sup>3</sup> In this method, the relationship between teeth and bone can be analyzed by means of dental casts. Furthermore, the methods described by Moyer<sup>3</sup> or Proffit<sup>4</sup> can help to identify asymmetry by means of a ruler and a bow divider or a symmetric grid, respectively. More recently, advances in technology have allowed the transfer of plaster models to a computer by using scanners.<sup>5</sup> They have also enabled three-dimensional models to be created on the basis of data obtained from Cone Beam Computed Tomography (CBCT), reproducing the patient's teeth and surrounding bone structures.<sup>6</sup> These models, however, are not linked to the patient's face anatomy; therefore, the advantages that a CBCT can provide, such as skeletal and dental diagnosis, are not used to their full potential. With a view to addressing such issue, some computer programs allow navigation in CBCT data through tomographic slices taken in the three planes of space and, with adjustment of the threshold, it is possible to visualize, at the same time, the teeth, bone and soft tissues.<sup>7</sup> Thus, the aim of this study was to validate a method used to evaluate, by means of CBCT, dental asymmetry (molars, canine and dental midline) in relation to the skeletal midline.

## MATERIAL AND METHODS

Sample size calculation was carried out ( $\alpha = 0.05$ ;  $\beta = 0.2$ ;  $p_0 = 0.45$ ;  $p_1 = 0.90$ )<sup>8</sup> and revealed that ten patients would be enough for 10 observations (twice, 5 observers).

This study, approved by the Federal University of Rio de Janeiro Institutional Review Board, comprised ten patients who were being orthodontically treated and had CBCT taken. Patients were randomly selected. In selecting the sample, the following exclusion criteria were applied: absence of canines and incisors; presence of restorations at the evaluated sites; and syndromes, such as cleft lip and palate, by which maxillary bone formation could be affected.

The CBCT equipment used was an i-CAT (Imaging Sciences, Hatfield, PA), with a 13 x 17 cm field of view, voxel dimension of 0.4 mm and exposure time of 20 seconds. The images were obtained at 120 kVp and 5 mA. All patients were in maximum intercuspation during the scan.

After the images were taken, one operator imported all DICOM (Digital Images and Communication in Medicine) files into Dolphin 3D (Dolphin Imaging, version 11.0, Chatsworth, CA) software. For standardization purposes, the Frankfort Horizontal Plane was horizontally oriented for all patients. In addition, slice thickness was set to be equal to the voxel size. Patients' data were saved and all the observers started taking the measurements at this point. Each observer had to orient the patient's head (turning to left or right, only) and had to try to match the skeletal midline with the sagittal plane (Fig 1),

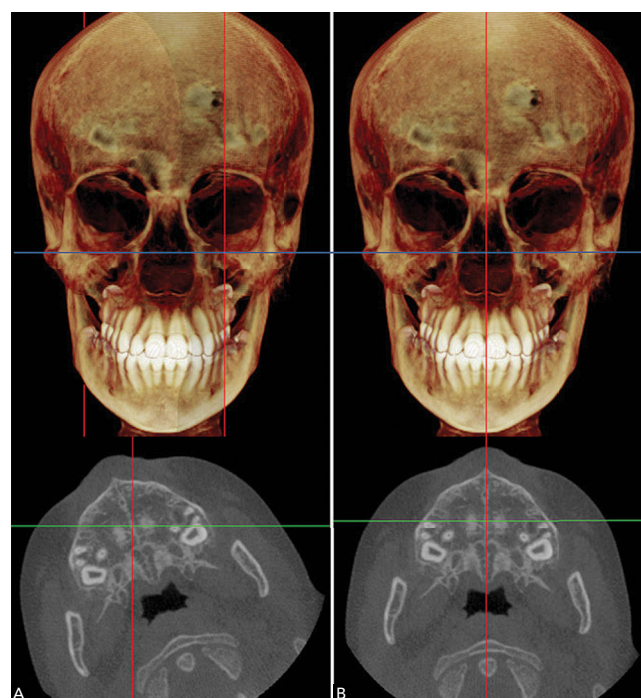


**Figure 1** - A) Example of a patient with the Frankfort Horizontal Plane horizontally oriented. B) After one operator reoriented the skeletal midline with the sagittal plane (red).

using nasion, anterior nasal spine and posterior nasal spine as reference, before beginning the analyses.

Five different observers — all students of Orthodontics, with one to two years of experience working with CBCT — were asked to test the reproducibility of 10 landmarks and 12 distances using the CBCT scans, as shown in Tables 1 and 2. Calibration was done

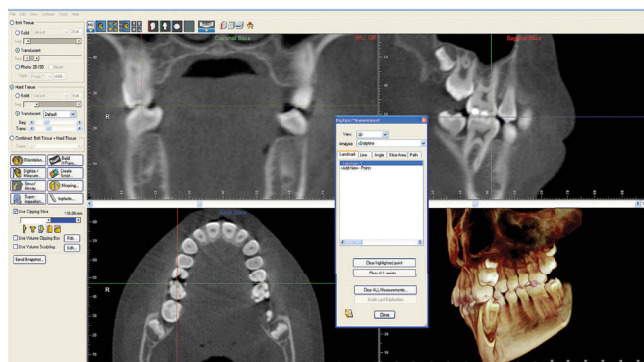


**Figure 2** - Example of landmark positioning. After being identified in three different slices, the landmark was plotted in the axial view of the multiplanar reconstruction (lower left box).

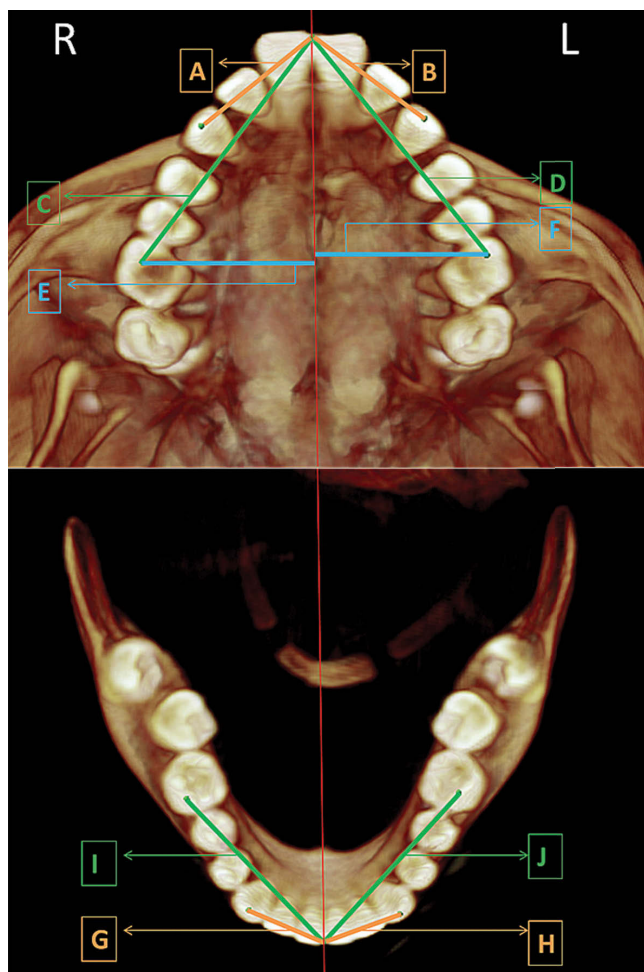


**Figure 3** - Linear distances as shown in Table 2.

with two scans that were not included in the sample. Evaluations were carried out independently and repeated within an interval of ten days. For more accuracy in the following step, the size of the landmarks was set at 0.01 mm. All four views (sagittal, axial, coronal and the rendered image) were used as reference to locate the landmarks. However, landmarks were only plotted in the axial slices of the multiplanar reconstruction (Fig 2). Figure 3 and 4 show the distances between the landmarks used in the study.

Landmarks and distances were obtained by means of the Digitize/Measurement tool available in the 3D view of the software. After all landmarks were plotted, the next step was to measure the distance between them. The software did not allow automatic connection between two landmarks. For this reason, this step had to be taken manually. To calculate the distance between two landmarks, the observer only connected the landmarks of interest. Both landmarks and distances were exported to Microsoft Excel (Microsoft Corporation, Redmond, WA).

## STATISTICAL ANALYSES

Analyses were carried out with the Statistical Package for the Social Sciences 17.0 (Chicago, IL, USA). Intra-examiner and inter-examiner reliability values for both landmarks and distances were determined by using intraclass correlation coefficients (ICCs).

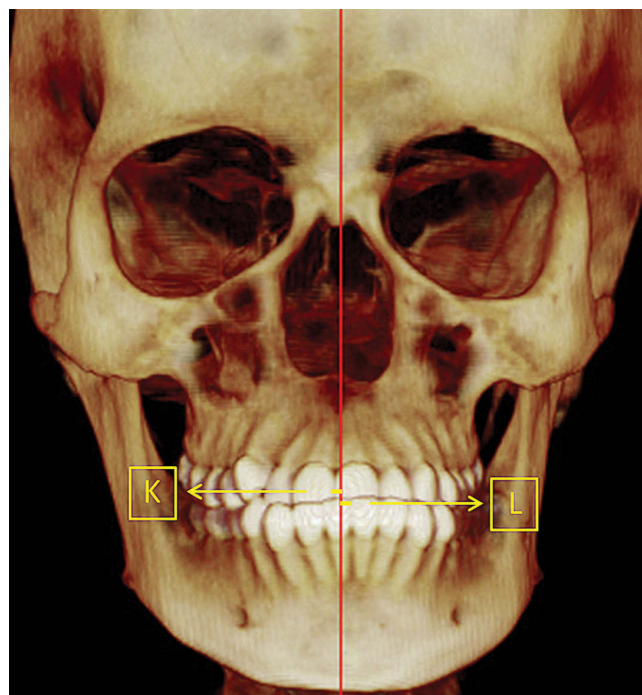


**Figure 4** - Linear distances as shown in Table 2.

**Table 1** - Localization of the landmarks used in the study.

| Landmark        | Anatomic region                                 | Coronal slice                               | Axial slice                   | Sagittal slice               |
|-----------------|-------------------------------------------------|---------------------------------------------|-------------------------------|------------------------------|
| <b>Maxilla</b>  |                                                 |                                             |                               |                              |
| UR6             | Right molar mesiobuccal cusp tip                | Middle-inferior-most point                  | Middle point                  | Middle-inferior-most point   |
| UR3             | Right canine cusp tip                           | Middle-inferior-most point                  | Middle point                  | Middle-inferior-most point   |
| UML             | Skeletal midline at upper incisors incisal edge | Middle-inferior-most point between incisors | Middle point between incisors | Anterior-inferior-most point |
| UL6             | Left molar mesiobuccal cusp tip                 | Middle-inferior-most point                  | Middle point                  | Middle-inferior-most point   |
| UL3             | Left canine cusp tip                            | Middle-inferior-most point                  | Middle point                  | Middle-inferior-most point   |
| <b>Mandible</b> |                                                 |                                             |                               |                              |
| LR6             | Right molar mesiobuccal cusp tip                | Middle-superior-most point                  | Middle point                  | Middle-superior-most point   |
| LR3             | Right canine cusp tip                           | Middle-superior-most point                  | Middle point                  | Middle-superior-most point   |
| LML             | Skeletal midline at lower incisors incisal edge | Middle-superior-most point between incisors | Middle point between incisors | Anterior-superior-most point |
| LL6             | Left molar mesiobuccal cusp tip                 | Middle-superior-most point                  | Middle point                  | Middle-superior-most point   |
| LL3             | Left canine cusp tip                            | Middle-superior-most point                  | Middle point                  | Middle-superior-most point   |

**Table 2** - Distance between landmarks.

|                 |                                                                          |
|-----------------|--------------------------------------------------------------------------|
| <b>Maxilla</b>  |                                                                          |
| Distance A      | Distance between UR3 and UML                                             |
| Distance B      | Distance between UL3 and UML                                             |
| Distance C      | Distance between UR6 and UML                                             |
| Distance D      | Distance between UL6 and UML                                             |
| Distance E      | Distance between UR6 90° to the skeletal midline                         |
| Distance F      | Distance between UL6 90° to the skeletal midline                         |
| <b>Mandible</b> |                                                                          |
| Distance G      | Distance between LR3 and LML                                             |
| Distance H      | Distance between LL3 and LML                                             |
| Distance I      | Distance between LR6 and LML                                             |
| Distance J      | Distance between LL6 and LML                                             |
| <b>Midline</b>  |                                                                          |
| Distance K      | Distance between the skeletal midline and the midline of the upper teeth |
| Distance L      | Distance between the skeletal midline and the midline of the lower teeth |

Average mean differences for the distances measured by different examiners (measurement errors) were summarized, and descriptive statistics were applied. The paired t-test was also applied to detect significant mean differences. The level of significance was set at 0.05.

## RESULTS

The reliability in defining the landmarks was estimated by ICC for each coordinate of each landmark. As a result, 30 variables (x, y and z for each landmark) were tested. The ICC was  $\geq 0.9$  for 27 (90%) of all intraobserver assessments, and the lowest intraobserver coefficient was 0.706. The ICC was  $\geq 0.9$  for 25 (83%) for all interobserver assessments, and the lowest interobserver coefficient was 0.591.

Table 3 shows the frequency of intraobserver and interobserver reliability estimated by ICC for the distances measured.

Table 4 shows the frequency of the mean difference for the distances measured by each observer. The mean difference was calculated using paired t-tests performed between every two observers for each distance. The results are summarized in Table 4 and illustrate that 10 (83%) measurements had a very small mean difference of less than 0.5 mm and no measurement had a mean difference greater than 1 mm.

Table 5 lists the reliability estimated by ICC and the interobserver mean difference for each distance.

## DISCUSSION

Only skeletal structures were used to define the skeletal midline in this study. The references used were

**Table 3** - Frequency of intra and interobserver reliability estimated by intraclass correlation coefficient (ICC) for the distances measured.

| Values                 | Intraobserver |     | Interobserver |     |
|------------------------|---------------|-----|---------------|-----|
|                        | n             | (%) | n             | (%) |
| ICC $\geq$ 0.90        | 7             | 58  | 5             | 42  |
| 0.75 < ICC < 0.90      | 5             | 42  | 4             | 33  |
| 0.45 < ICC $\leq$ 0.75 | 0             | 0   | 3             | 25  |
| ICC $\leq$ 0.45        | 0             | 0   | 0             | 0   |
| Total                  | 12            | 100 | 12            | 100 |

**Table 4** - Frequency of the mean difference among observers on the distances measured.

| Values (mm)      | n  | (%) |
|------------------|----|-----|
| $\geq 2$         | 0  | 0   |
| 1 < x < 2        | 0  | 0   |
| 0.5 < x $\leq$ 1 | 2  | 17  |
| $\leq 0.5$       | 10 | 83  |
| Total            | 12 | 100 |

**Table 5** - Reliability estimated by intraclass correlation coefficient (ICC) for each distance.

| Distances | Intraobserver reliability | Interobserver reliability | Interobserver mean difference (mm) |
|-----------|---------------------------|---------------------------|------------------------------------|
| A         | 0.932                     | 0.920                     | 0.31                               |
| B         | 0.883                     | 0.859                     | 0.34                               |
| C         | 0.959                     | 0.934                     | 0.35                               |
| D         | 0.969                     | 0.900                     | 0.54                               |
| E         | 0.886                     | 0.916                     | 0.60                               |
| F         | 0.949                     | 0.867                     | 0.41                               |
| G         | 0.813                     | 0.862                     | 0.23                               |
| H         | 0.917                     | 0.741                     | 0.26                               |
| I         | 0.893                     | 0.866                     | 0.50                               |
| J         | 0.963                     | 0.946                     | 0.22                               |
| K         | 0.781                     | 0.591                     | 0.35                               |
| L         | 0.958                     | 0.740                     | 0.38                               |

landmarks such as anterior and posterior nasal spine and nasion. Differently from other studies using CBCT,<sup>9,10</sup> only the Frankfort Horizontal Plane was pre-oriented and each individual observer later established the skeletal midline. The reason was that if the head was already oriented with the skeletal midline in the sagittal plane, it would increase the likelihood for bias and make it easier for each observer to define the plane.

Head orientation does not influence linear measurements;<sup>11</sup> as long as the same landmarks were obtained, measurements should be the same.

Grauer et al<sup>7</sup> demonstrated that landmarks are better located when plotted in the stack of slices rather than in rendered images. This technique was employed by our study of which results corroborate the findings of other researches that showed high values for intraclass<sup>9,10</sup> and interclass<sup>9,12</sup> correlation for landmarks identified in dental structures.

Creed et al<sup>6</sup> showed that anteroposterior measurements for molars can be reliably taken using either digital models or surface models made on the basis of CBCT data. Asquith et al<sup>13</sup> investigated dental casts and 3D digital study models and found that intraexaminer mean differences for this variable were  $\leq 0.05$  mm and  $\leq 0.32$  mm, respectively. Our study had slightly higher mean differences; however, it was interexaminer instead of intraexaminer. In addition, the values were not clinically significant (all of them  $\leq 0.54$  mm). The present research also confirmed that the same type of anteroposterior evaluation can be applied for the canines.

Mean difference between observers for distances from skeletal to dental midlines were  $\leq 0.4$  mm. The other transversal measurement, molars perpendicular line to the skeletal midline, showed good reliability between observers. Other techniques have been applied for this evaluation. However, conventional or 3D digital models can use only the palatal rugae as reference, which is reliable for growing patients.<sup>14</sup> Nonetheless, using the raphe as the skeletal midline may not be the best option, as it has different shapes and curvatures.<sup>1</sup> Nevertheless, skeletal midline and raphe have been associated in the past.<sup>15</sup> With 3D surface models, one can obtain other structures that would likely provide a reliable skeletal midline. However, the production of these models involves either hiring a specialized company, which implies in higher costs,<sup>6</sup> or computer expertise, which is extremely time consuming.<sup>9,16</sup> To our view, the process involved in any of these options does not outweigh the benefits.

The advantages of the proposed method are as follows: the possibility of assessing and reproducing patients' skeletal midline and relating it to the teeth and soft tissues, and the possibility of directly taking measurements in the CBCT slices by means of simple techniques. Based on recent controversies, the main disadvantage is that not every patient needs a CBCT scan. Additionally, even though it

is an important piece of data that can be obtained for cases of skeletal asymmetry, we do not recommend that CBCT scans be taken for this purpose only. In spite of being recommended for very specific cases, CBCT scans have lower radiation doses,<sup>17,18</sup> lower costs and good accuracy.<sup>19</sup> For this reason, the exam has been increasingly used, in addition to becoming more accepted.<sup>20</sup> The radiation doses involved in this type of exam are similar to those of a full-mouth series of radiographs. Furthermore, one single CBCT scan is able to provide data for airway, sinus and TMJ analyses.<sup>21,22</sup> On the other hand, another drawback is the potential presence of artifacts in the areas of interest and the need for specific software for evaluation.

Clinically determining dental midline shifts using the soft tissue as reference can be misleading when there are asymmetries in nose, chin or philtrum.<sup>23</sup> The proposed “imaginary plumb” method<sup>24</sup> as a true vertical line is affected by the patient and operator position as well as the parallax effect.

Anteroposterior dental asymmetry is often present in subdivision malocclusions. It can be corrected by means of minor dental movements or extractions depending on the degree of the discrepancy. It is necessary to diagnose in which arch and side the asymmetry is located to decide which mechanics will be applied. The evaluation on dental casts will use the raphe as the skeletal midline, but some degree of variation might occur between different operators due to the shape of the raphe. Therefore, evaluating dental asymmetry by means of CBCT images and having the skeletal midline as reference provides useful information for diagnosis.

## CONCLUSION

Measurements for molars, canines and incisors in relation to the skeletal midline taken to assess dental asymmetry are reproducible and reliable when taken by means of CBCT.

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# Nicotine effect on bone remodeling during orthodontic tooth movement: Histological study in rats

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**Introduction:** Nicotine is harmful to angiogenesis, osteogenesis and synthesis of collagen.

**Objective:** The aim of this study was to investigate the effect of nicotine on bone remodeling during orthodontic movement in rats.

**Methods:** Eighty male Wistar rats were randomly divided into three groups: Group C (control), group CM (with orthodontic movement) and group NM (nicotine with orthodontic movement) groups. The animals comprising groups C and CM received 0.9% saline solution while group NM received nicotine solution (2 mg/kg). A nickel-titanium closed-coil spring was used to induce tooth movement. The animals were euthanized and tissue specimens were processed histologically. We quantified blood vessels, Howship's lacunae and osteoclast-like cells present in the tension and compression areas of periodontal ligaments. The extent of bone formation was evaluated under polarized light to determine the percentage of immature/mature collagen.

**Results:** We observed lower blood vessel densities in the NM group in comparison to the CM group, three ( $p < 0.001$ ) and seven ( $p < 0.05$ ) days after force application. Osteoclast-like cells and Howship's lacunae in the NM group presented lower levels of expression in comparison to the CM group, with significant differences on day 7 ( $p < 0.05$  for both variables) and day 14 ( $p < 0.05$  for osteoclast-like cells and  $p < 0.01$  for Howship's lacunae). The percentage of immature collagen increased in the NM group in comparison to the CM group with a statistically significant difference on day 3 ( $p < 0.05$ ), day 7 ( $p < 0.001$ ), day 14 ( $p < 0.001$ ) and day 21 ( $p < 0.001$ ).

**Conclusions:** Nicotine affects bone remodeling during orthodontic movement, reducing angiogenesis, osteoclast-like cells and Howship's lacunae, thereby delaying the collagen maturation process in developed bone matrix.

**Keywords:** Tooth movement. Bone resorption. Bone formation. Blood vessels. Nicotine.

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

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## INTRODUCTION

Smoking and other forms of tobacco use are major risk factors for cardiovascular disease. The effect of cigarette smoking on cardiovascular health is evident even at the lowest levels of exposure.<sup>1</sup> Nicotine (*Nicotiana tabacum*) is the most pharmacologically active component present in tobacco and directly or indirectly affects cellular metabolism, reducing angiogenesis;<sup>2</sup> osteogenesis;<sup>3,4</sup> fibroblasts proliferation and adhesion as well as collagen synthesis.<sup>5</sup>

According to Hollinger et al<sup>6</sup> and Feitelson et al,<sup>7</sup> nicotine exhibits broad pharmacological action, of which the biggest effect is vasoconstriction. Zhu and Parmley<sup>8</sup> reported that the mechanisms that produce this vasoconstriction are associated with local or systemic catecholamine release, sympathetic neural stimulation, and endothelial dysfunction. Nicotine induces norepinephrine release from postganglionic sympathetic nerves, innervating blood vessels through a direct action on the nerve terminals.<sup>9</sup> Consequently, systemic and local actions occur, which can influence the biological processes that require higher metabolic activity.<sup>2,3</sup>

The early phase of orthodontic tooth movement always involves an acute inflammatory response, characterized by periodontal vasodilatation and migration of leucocytes out of the capillaries. These migratory cells produce various cytokines, the local biomechanical signal molecules that interact with the entire population of native paradental cells. Cytokines evoke the synthesis and secretion of numerous mediators by target cells, including growth factors, prostaglandins and other cytokines. Subsequent biological events occur and result in bone remodeling to accommodate movement of the tooth.<sup>10,11</sup>

Bone resorption and bone formation are parts of the remodeling process during orthodontic tooth movement. Bone is deposited on the alveolar wall on the tension side of the tooth with both heavy and light forces, and newly formed bone spicules follow the orientation of the periodontal fiber bundles. On the pressure side, with light forces, alveolar bone is directly resorbed by numerous osteoclasts in Howship's lacunae.<sup>11</sup>

Although there are more than 1.3 billion of smokers in the world<sup>12</sup> and the acceptance of the fact that nicotine acts on cellular and tissue metabolism is widespread,

there are no reports in the literature demonstrating the action of nicotine on orthodontic movement.

Thus, the aim of this study was to investigate the effect of nicotine on bone remodeling during orthodontic movement induced in rats.

## MATERIAL AND METHODS

The present study was approved by the Committee on Animal Research and Ethics of the Catholic University of Paraná (PUCPR), under protocol number 199/07.

A total of 80 male Wistar albino rats, 12 weeks old and weighing from 250 to 300 g, were used in this study. Animals were kept in polycarbonate boxes at temperatures ranging between 19°C and 22°C, with a standard 12-hour light-dark cycle. They were fed a diet of finely ground laboratory food *ad libitum* to minimize any discomfort to the animal following orthodontic appliance placement. The animals weight decreased during the experiment, but without significantly statistic differences ( $p > 0.05$ ).

The rats were divided into three groups: Group C (control), group CM (with orthodontic movement) and group NM (nicotine with orthodontic movement). The study focused on the mesio-buccal roots of maxillary first molars. The right hemi-maxillae comprised groups CM and NM (40 rats in each) while the left hemi-maxillae comprised group C. The use of contralateral molars as control was according to Ong et al,<sup>13</sup> Kalia et al,<sup>14</sup> Bletsa et al,<sup>15</sup> and Ren et al.<sup>16</sup>

The animals of groups C and CM received 0.9% saline solution at 0.5 ml/kg every 24 hours so as to simulate stress. Group NM received daily doses of 2 mg/kg nicotine solution (98% PA solution diluted in 0.9% saline solution), subcutaneously. The dosage was based on the study conducted by Chen et al.<sup>17</sup> The applications began one day before orthodontic appliance placement and were reapplied once a day during the experimental periods of three, seven, 14 and 21 days.

Orthodontic movement was induced by nickel-titanium closed-coil springs (G&H® Wire Company REF CCOF9XL Lote 103946 Hanover, Germany) that applied a reciprocal force between the maxillary right first molar and central incisors (Fig 1) of 30 g/f

magnitude, measured by a Dynamometer gauge (Dentaurum model stress and tension gauge, 25-250 g/f). The coil spring was inserted while the animal was sedated with intramuscular injection of 1.8 mg/kg ketamine (Vetanarcol®, Konig, Avellaneda, Argentina) and 1.1 mg/kg xylazine (Rompun®, Bayer, Lote 00404, São Paulo, Brazil). During the experiment, all coil springs were evaluated and should any of them fail, the animal would be replaced by another one.

Animals were euthanized three, seven, 14 and 21 days after the orthodontic appliance was placed, with ketamine (5.4 mg/kg) and xylazine (3.3 mg/kg), via intraperitoneal injection. After euthanasia, the maxillae were immediately removed and fixed in 10% neutral formalin for 72 hours. The resulting blocks were decalcified for approximately 12 weeks in a 4.13% EDTA aqueous solution. 5- $\mu$ m-thick transversal cuts were obtained and stained by means of conventional methods. From each maxillary block, 16 cuts were obtained from the alveolar crest up to the apices; 12 of which were stained with hematoxylin-eosin (HE) and four with picosirius.

The histological study was performed by one operator, blinded to treatment allocation. Osteoclast-like cells, active Howship's lacunae and blood vessels were

quantified under 400 x magnification using a light microscope. The histologic criterion used to identify the osteoclast-like cells was the presence of multinuclear and eosinophilic cells on the bone surface.<sup>18</sup>

Histological sections stained by the picosirius method were viewed under 100 x magnification with a polarized light microscope. This method allows an indirect evaluation of the stage of bone matrix organization based on birefringence of the collagen fiber bundles.<sup>19</sup> The analysis was performed by 4.5 Image Pro-Plus® software (Media Cybernetics, Silver Spring, MD, USA) which calculated the percentages of immature and mature collagen present on bone matrix proximal to the tension area.

The mean values obtained were statistically analyzed by means of the SPSS 15.0 (SPSS Inc, Chicago, IL, USA) and Statistica 8.0 (StatSoft, Inc, Tulsa, OK, USA) software. The Kolmogorov-Smirnov test and Levene test were used to evaluate normality for each treatment and the homogeneity of variance between treatments. When the tests indicated non-normal distribution and heterogeneity of variance between treatments, we applied the non-parametric test and the non-parametric Kruskal-Wallis test for multiple comparisons. When the tests indicated normal distribution

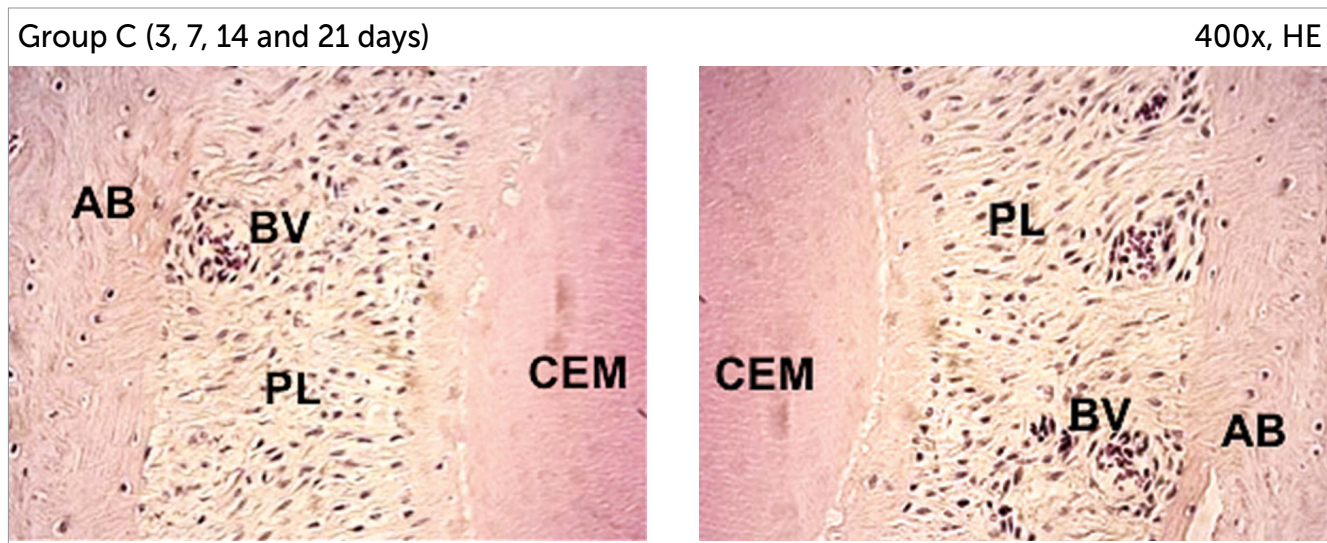


**Figure 1** - First molar mesiobuccal roots photomicrographs from group C (AB= alveolar bone; CEM= cementum; PL= periodontal ligament; BV= blood vessels).

and homogeneity of variance, we used ANOVA and the Student's t-test for independent samples. The level of significance was  $p < 0.05$  when comparing the averages between treatments and groups.

## RESULTS

### Histology

The histological study demonstrated characteristic structural aspects among different groups throughout the experimental period.

#### Group C

The periodontal ligament showed moderate vascularization, with uniform width and irregular shape. The collagen fibers ran parallel and inserted perpendicular to the cementum and bone surface. On the bone surface, rare Howship's lacunae associated with osteoclast-like cells were observed (Fig 1).

#### Group CM

In the sections of these samples, on day three, the collagen fibers were elongated on the tension areas, compressed and completely disorganized on the compression areas. We also observed angiogenesis with congested vessels. The compression area showed irregular alveolar bone due to a small population of osteoclast-like cells localized on Howship's lacunae. Hyalinized areas were not present (Fig 2). The bone matrix under polarized light demonstrated a predominance of greenish, immature fibers with irregular birefringence and few yellowish-orange fibers (Fig 6).

On day seven, the compression area showed active resorption, with accumulation of osteoclast-like cells associated with numerous Howship's lacunae. In the tension area, the fibers were elongated and better organized (Fig 3). We observed deposition of thicker and yellowish-orange collagen fibers, forming

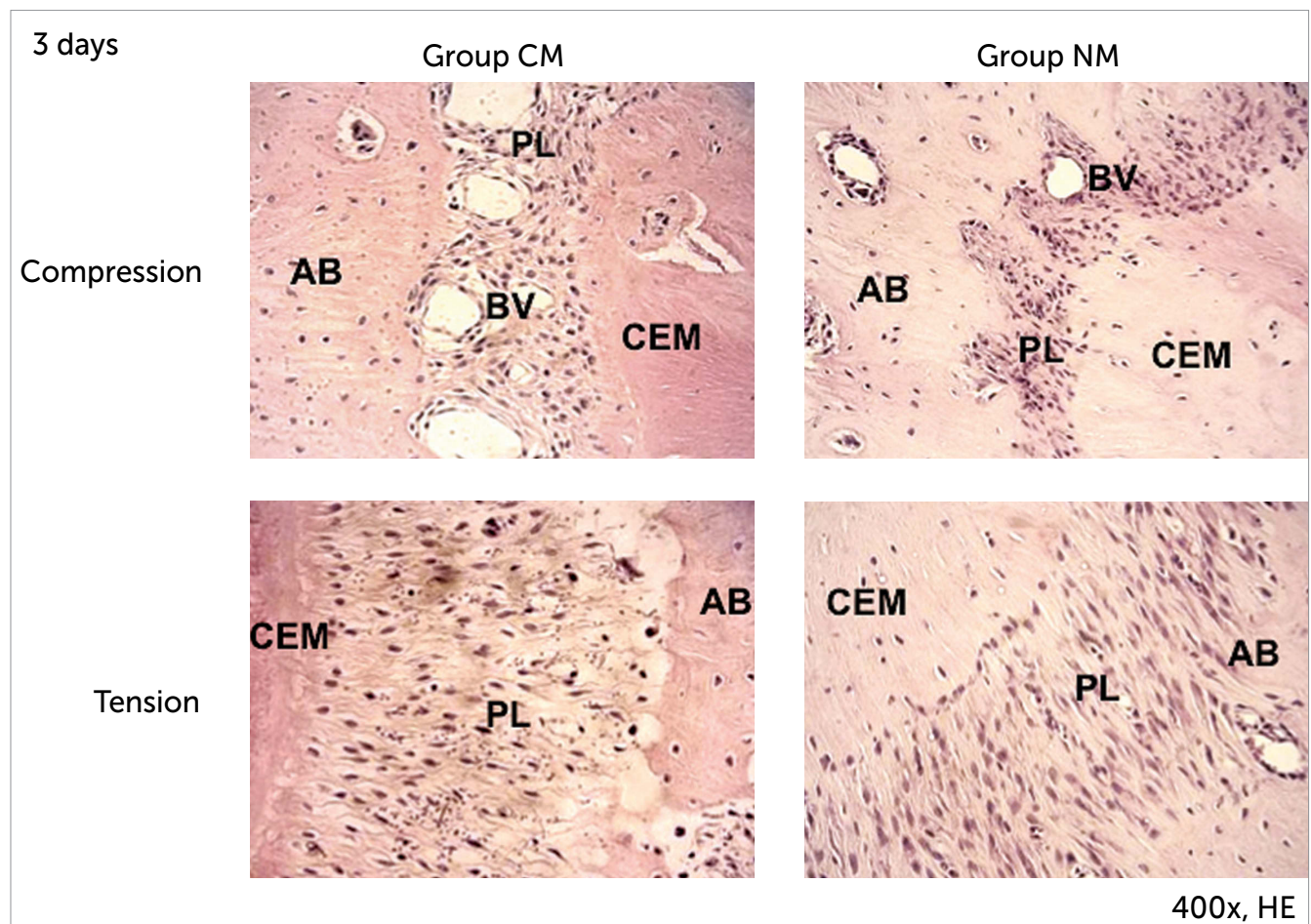


**Figure 2** – First molar mesiobuccal roots photomicrographs from groups CM and NM. Compression and Tension areas 3 days (HE – original magnification x400). AB, alveolar bone; CEM, cementum; PL, periodontal ligament; BV, blood vessels.

more compact areas (Fig 6). On day 14, in the compression area, osteoclast-like cells and Howship's lacunae were limited in number (Fig 4). In the tension area, the periodontal ligament displayed aspects of normality (Fig 7). The developed bone matrix was completely filled by red and thick collagen fibers.

On day 21, we observed that osteoclast-like cells and Howship's lacunae returned to normal basal expression levels in the compression area. In the tension area, the collagen fibers were more organized, parallel, and inserted perpendicular to the alveolar bone and cementum (Fig 5). The developed bone matrix was filled by mature collagen (Fig 7).

### Group NM

On day three, we observed the compression and tension areas. The periodontal ligament on the compression side demonstrated nearly none osteoclast-like cells or Howship's lacunae. No hyalinized zones were present. In the tension area, the periodontal ligament fibers were elongated, oriented parallel to the root. Some blood vessels were visualized (Fig 2). Under polarized light, we observed a predominance of greenish and thinner fibers in the bone matrix (Fig 6). On day seven, the compression area showed some osteoclast-like cells and Howship's lacunae. No hyalinized zones were present.

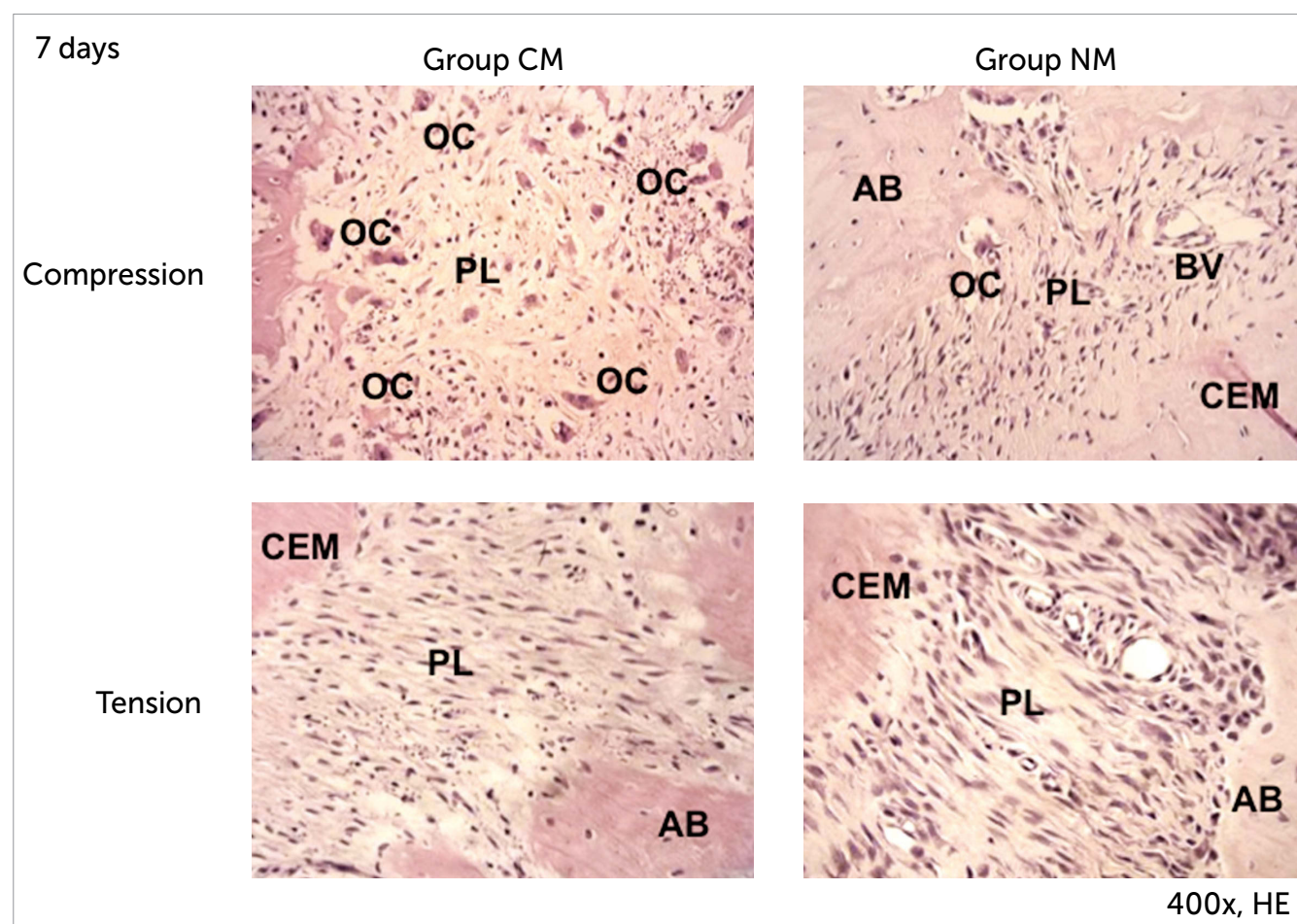


**Figure 3** - First molar mesiobuccal roots photomicrographs from groups CM and NM. Compression and Tension areas 7 days (HE – original magnification x400). AB, alveolar bone; CEM, cementum; PL, periodontal ligament; BV, blood vessels; OC, osteoclast-like cells.

In the tension area, the fibers were elongated and fewer blood vessels were visualized (Fig 3). We observed a predominance of greenish collagenous fibers, extending in several directions, with irregular birefringence (Fig 6).

On day 14, in the compression area, the periodontal ligament fibers were disorganized and irregular; few Howship's lacunae and osteoclast-like cells were present. In the tension area, the periodontal ligament fibers remained elongated and few blood vessels were visualized (Fig 4). The bone matrix presented a large number of greenish fibers (Fig 7). On day 21, in the compression and tension areas, the periodontal ligament

fibers were disorganized. Few osteoclast-like cells, Howship's lacunae and blood vessels were present (Fig 5). It was possible to verify, in the bone matrix, a large number of greenish fibers, thick and parallel to each other, as well as a few thinner red fibers (Fig 7).

### Quantitative analysis

All means, standards-deviation (SD) and p-values obtained are shown in Tables 1 and 2.

When groups C and CM were compared, there was an increase in the number of blood vessels on the third day after force application ( $p < 0.05$ ), with a decrease after days seven ( $p < 0.05$ ), 14 ( $p < 0.01$ ) and

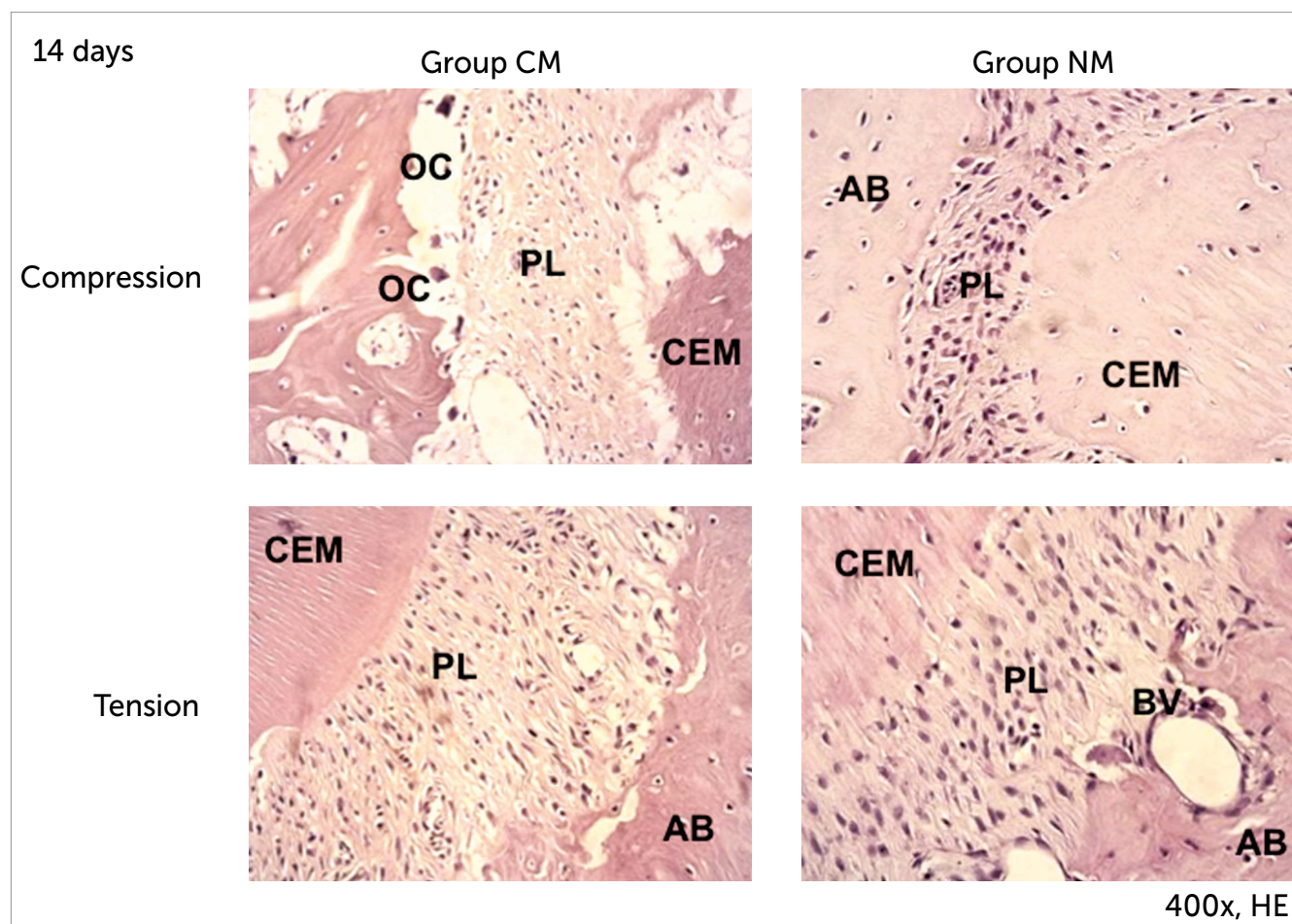


**Figure 4** - First molar mesiobuccal roots photomicrographs from groups CM and NM. Compression and Tension areas 14 days (HE – original magnification x400). AB, alveolar bone; CEM, cementum; PL, periodontal ligament; BV, blood vessels; OC, osteoclast-like cells.

21 ( $p < 0.001$ ) (Table 1). There was a greater number of osteoclast-like cells and Howship's lacunae in group CM when compared to the C group on days three ( $p < 0.001$ ), seven ( $p < 0.001$ ) and 14 ( $p < 0.01$ ).

Fewer blood vessels were observed in all periods analyzed in group NM in comparison to group C (Table 1). Osteoclast-like cells and Howship's lacunae were reduced on the third day after the application of force ( $p < 0.05$ ).

The quantity of blood vessels decreased in group NM after days three ( $p < 0.001$ ) and seven ( $p < 0.05$ ) when compared to group CM. Group NM had lower levels of osteoclast-like cells and Howship's lacunae, with a statistically significant difference on days seven and 14 (Table 1) in relation to group CM.

Immature collagen increased in group NM in comparison to group CM in all periods analyzed, with a statistically significant difference (Table 2).

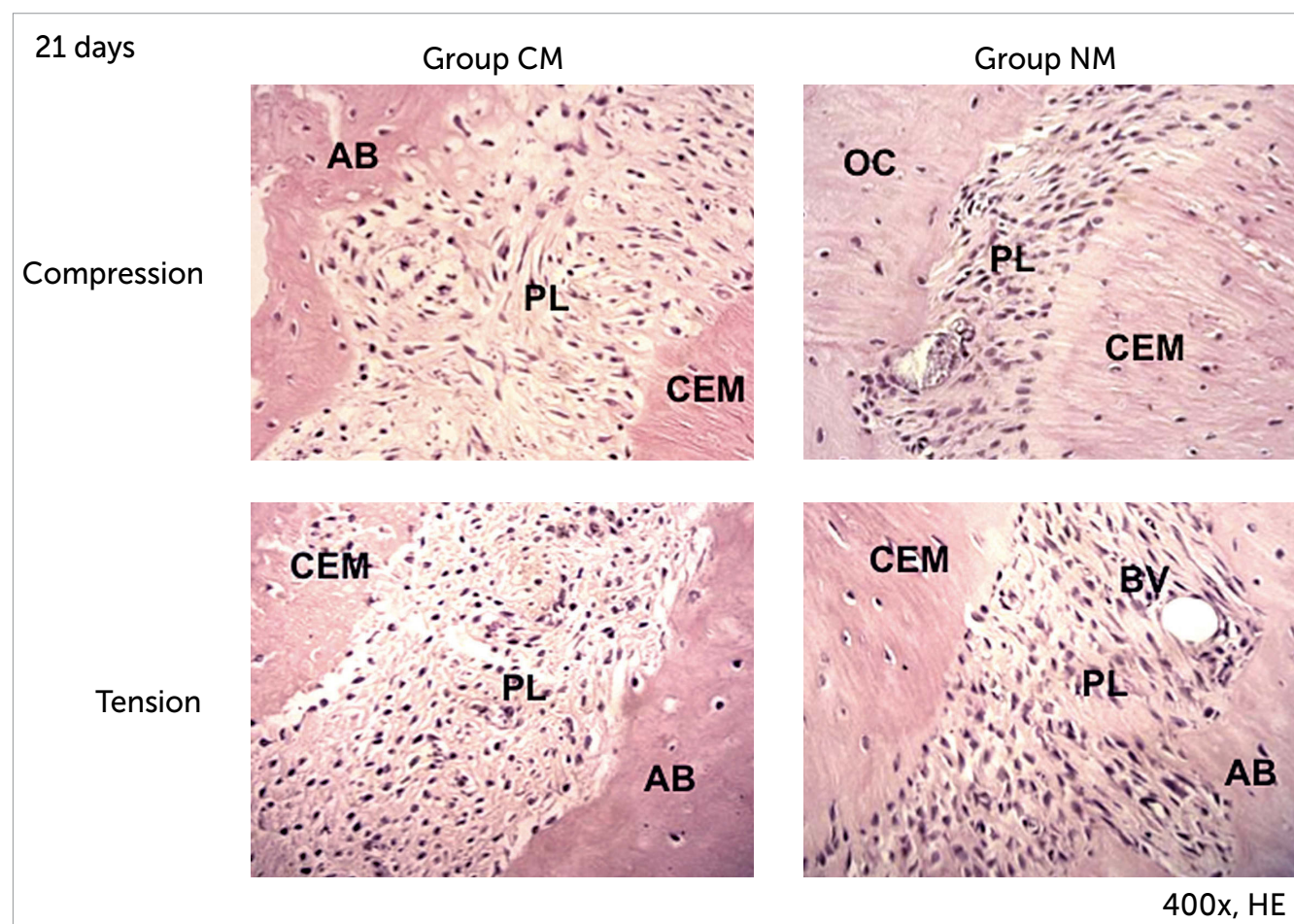


**Figure 5** - First molar mesiobuccal roots photomicrographs from groups CM and NM. Compression and Tension areas: 21 days (HE – original magnification x400). AB, alveolar bone; CEM, cementum; PL, periodontal ligament; BV, blood vessels.

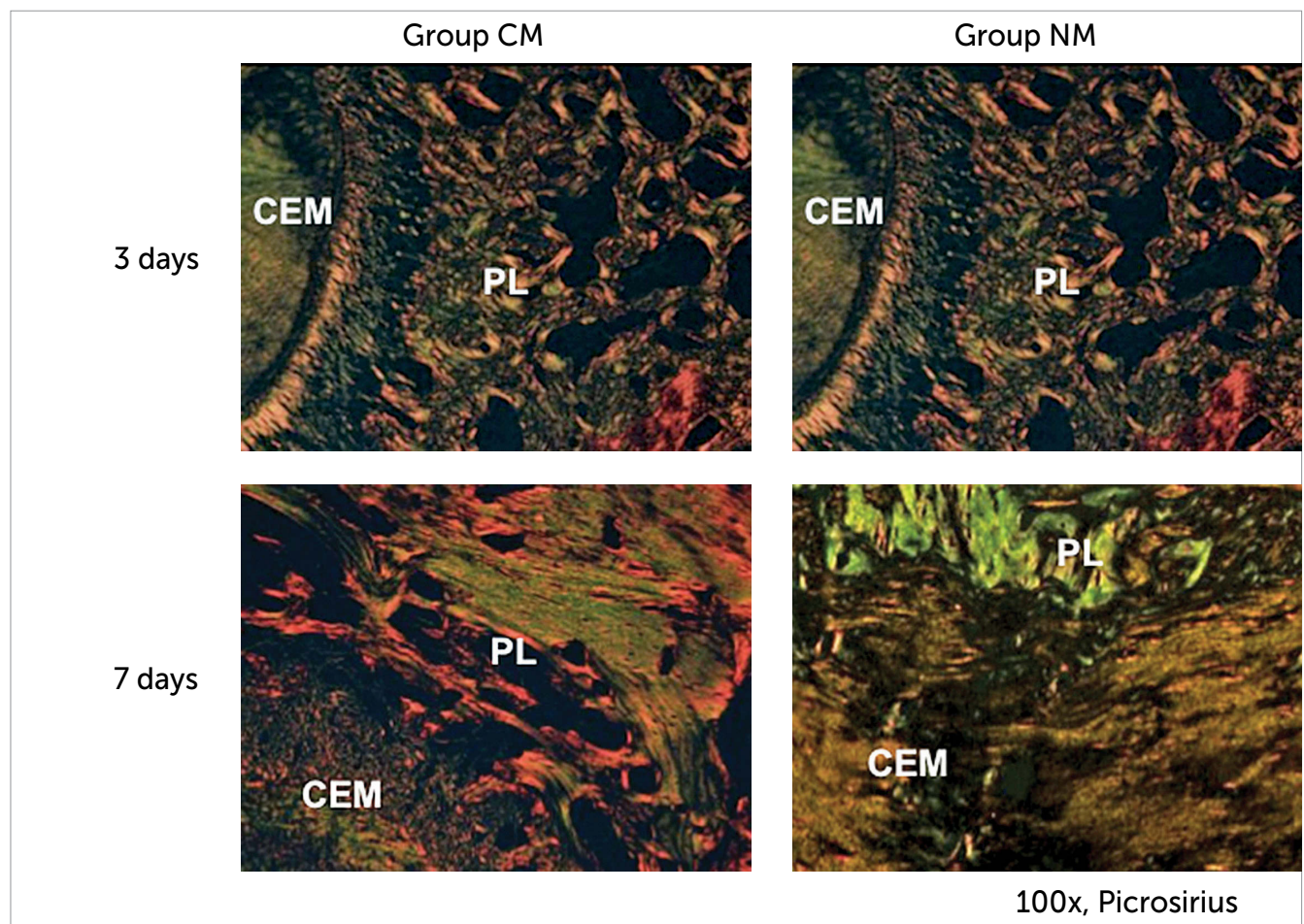


**Figure 6** - First molar mesiobuccal roots photomicrographs groups CM and NM. Tension areas: 3 and 7 days (picrosirius – original magnification x100). CEM, cementum; PL, periodontal ligament.

**Table 1** - Means, standard deviations and p values, according to groups and days.

| Variable               | Day | C<br>Mean $\pm$ SD | CM<br>Mean $\pm$ SD | NM<br>Mean $\pm$ SD | Inter-group differences<br>(p) |
|------------------------|-----|--------------------|---------------------|---------------------|--------------------------------|
| Osteoclasts-like cells | 3   | 0.6 $\pm$ 0.84     | 6.3 $\pm$ 1.34      | 3.6 $\pm$ 1.35      | ***C x CM. *C x NM             |
|                        | 7   | 0.5 $\pm$ 0.71     | 16.9 $\pm$ 3.35     | 2.2 $\pm$ 1.14      | ***C x CM. *CM x NM            |
|                        | 14  | 0.7 $\pm$ 0.95     | 3.3 $\pm$ 1.06      | 1.2 $\pm$ 1.62      | **C x CM. *CM x NM             |
|                        | 21  | 0.8 $\pm$ 0.92     | 14 $\pm$ 1.26       | 1.2 $\pm$ 1.32      | N.S.                           |
| Howship lacunae        | 3   | 0.4 $\pm$ 0.52     | 6.5 $\pm$ 1.96      | 3.1 $\pm$ 1.79      | ***C x CM. *C x NM             |
|                        | 7   | 0.3 $\pm$ 0.48     | 17.8 $\pm$ 2.57     | 1.9 $\pm$ 1.52      | ***C x CM. *CM x NM            |
|                        | 14  | 0.5 $\pm$ 0.71     | 3.9 $\pm$ 1.2       | 0.6 $\pm$ 0.97      | **C x CM. **CM x NM            |
|                        | 21  | 0.7 $\pm$ 0.82     | 1.0 $\pm$ 0.94      | 0.7 $\pm$ 1.06      | n.s.                           |
| Blood vessels          | 3   | 14.6 $\pm$ 1.26    | 25.5 $\pm$ 1.96     | 3.2 $\pm$ 1.93      | *C x CM. *C x NM; ***CM x NM   |
|                        | 7   | 14.9 $\pm$ 2.18    | 7.1 $\pm$ 1.45      | 2.4 $\pm$ 1.07      | *C x CM. ***C x NM. *CM x NM   |
|                        | 14  | 14.8 $\pm$ 2.04    | 3.1 $\pm$ 1.20      | 2.1 $\pm$ 1.66      | **C x CM. ***C x NM            |
|                        | 21  | 13.2 $\pm$ 1.55    | 3.1 $\pm$ 1.10      | 3.6 $\pm$ 1.58      | ***C x CM. **C x NM            |

Note: \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001 indicate statistically significant difference.

C = control / CM = induced movement / NM = induced movement+nicotine / NS = non-significant.

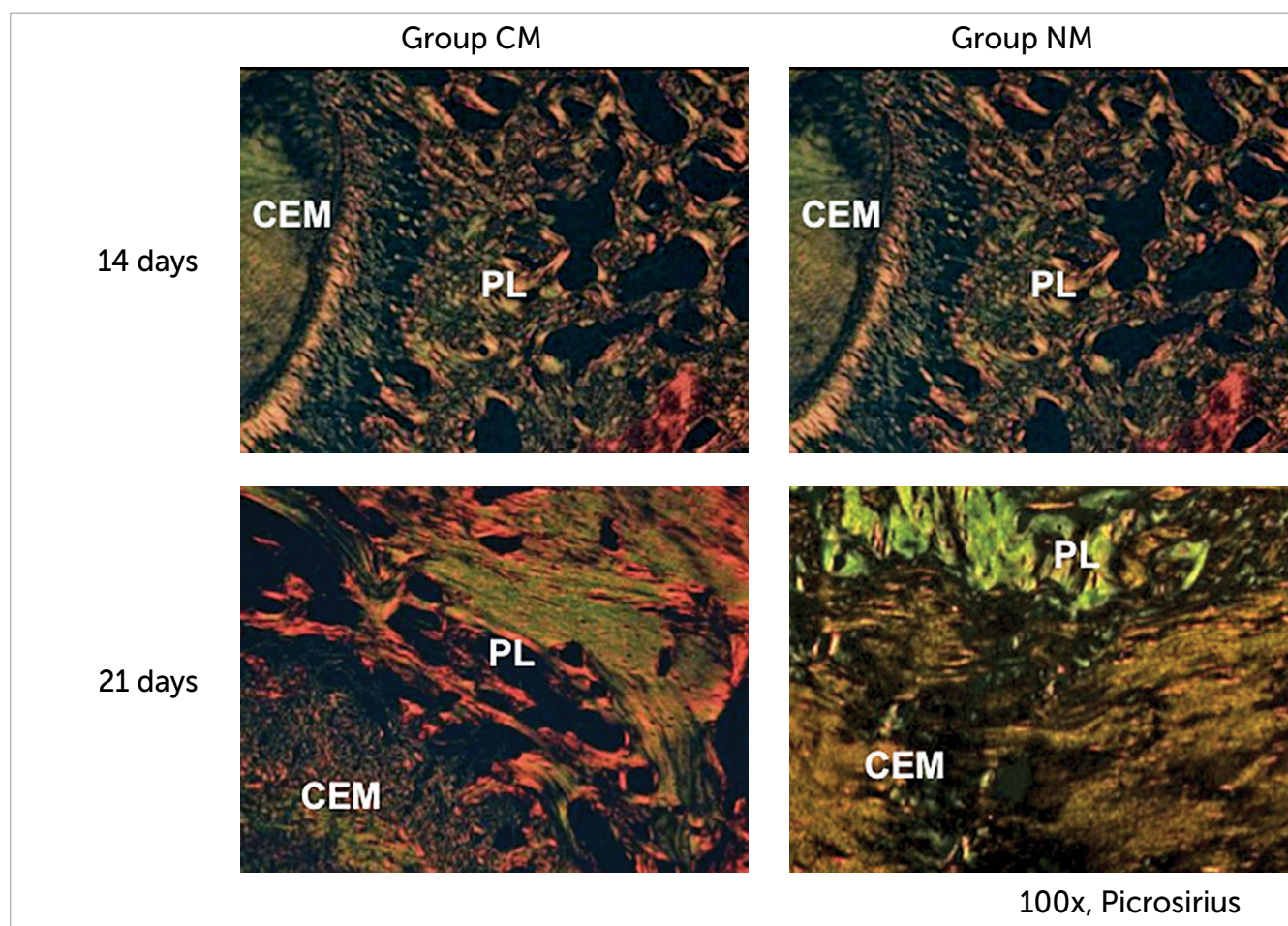


**Figure 7** - First molar mesiobuccal roots photomicrographs groups CM and NM. Tension areas: 14 and 21 days (picrosirius – original magnification x100). CEM, cementum; PL, periodontal ligament.

**Table 2** - Means, standard deviations and p values, according to groups and days

| Variable            | Day | CM<br>Mean + SD | NM<br>Mean + SD | Inter-group differences<br>(p) |
|---------------------|-----|-----------------|-----------------|--------------------------------|
| % Mature collagen   | 3   | 10.5 ± 2.84     | 5.8 ± 2.66      | *CM x NM                       |
|                     | 7   | 38.3 ± 4.30     | 7.8 ± 2.15      | ***CM x NM                     |
|                     | 14  | 100 ± 0         | 9 ± 2.98        | ***CM x NM                     |
|                     | 21  | 100 ± 0         | 11 ± 2.98       | ***CM x NM                     |
| % Immature collagen | 3   | 89.5 ± 2.84     | 94.2 ± 2.66     | *CM x NM                       |
|                     | 7   | 61.7 ± 4.30     | 92.2 ± 2.15     | ***CM x NM                     |
|                     | 14  | 0 ± 0           | 91 ± 2.98       | ***CM x NM                     |
|                     | 21  | 0 ± 0           | 89 ± 2.98       | ***CM x NM                     |

Note: \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001 indicate statistically significant difference.  
CM = induced movement/ NM = induced movement+nicotine / NS = non-significant.

## DISCUSSION

Nicotine is a major cytotoxic and vasoactive substance present in tobacco which causes peripheral vasoconstriction, tissue ischemia and decreased oxygen tension by reducing the infusion of oxygen to tissue. Furthermore, this substance decreases osteoblastic activity, revascularization and bone healing.<sup>5,20</sup>

In group NM, there were lower numbers of blood vessels when compared to group C for all periods analyzed (Table 1). When comparing groups NM x CM, we observed fewer blood vessels in group NM on days three ( $p < 0.001$ ) and seven ( $p < 0.05$ ), with a statistically significant difference (Table 1).

Pinto et al<sup>3</sup> reported that nicotine delays angiogenesis, and as a consequence, delays the organization of connective tissue and osteogenesis. Saldanha et al<sup>20</sup> demonstrated that administration of nicotine to jaw bone defects in dogs changes the density of newly formed bone tissue due to the inhibition of revascularization. Adversely, Zheng et al<sup>4</sup> concluded that nicotine exposure enhances angiogenesis in rabbit model, but cannot compensate the adverse effect of vasoconstriction.

There are controversies regarding the effect of nicotine on osteoclasts. Heremyre et al<sup>21</sup> observed that nicotine stimulates osteoclast-like cell differentiation in cell cultures derived from pigs; Tanaka et al<sup>22</sup> also observed increased formation of osteoclast-like

cells *in vitro*. We observed that nicotine reduced the expression of osteoclast-like cells and Howship's lacunae in group NM (Table 1). This result is in accordance with the findings by Yuhara et al<sup>23</sup> who demonstrated that nicotine inhibits differentiation and activation of osteoclast-like cells and regulates bone metabolism in rats. Adler et al<sup>24</sup> concluded that nicotine did not stimulate the formation of osteoclasts in bone marrow at doses of 1 or 2 mg / kg in rats.

In this study, we evaluated structural changes in the newly developed bone matrix when nicotine and orthodontic force were applied simultaneously. The picrosirius-polarization method allows the detection of mature and immature collagen and correlates the three-dimensional distribution of collagen fibers with the stage of bone formation.<sup>19</sup> The collagen color and birefringence vary according to polymerization degree, which reflects fibers' age and diameter. First, the collagen is deposited in the form of thin fibrils that aggregate to form larger fibers or bundles.<sup>25</sup>

The organic matrix of alveolar bone is composed fundamentally of type I collagen (95%), proteoglycans and glycoproteins.<sup>26</sup> Bone formation results from complex and inter-dependent processes, which involve osteoblast differentiation from primitive mesenchymal cells, organic matrix synthesis and maturation, until complete mineralization.<sup>27</sup>

The process of bone formation is associated with the formation of new capillaries from existing blood vessels.<sup>28</sup> Orthodontic movement results in a rapid formation of immature bone, and later, the bone is remodeled.<sup>29</sup>

Immature collagen percentage in group NM increased in all analyzed periods. On day 21, there were still immature fibers, although they were thicker and more parallel. Nicotine delayed the collagen maturation process in the developed bone matrix. It was not possible to assess whether nicotine was able to inhibit the

synthesis of collagen, although Theiss et al<sup>2</sup> showed that during bone healing in rabbits subjected to nicotine, there were lower levels of type I and II collagen mRNA.

## CONCLUSION

In conclusion, nicotine affects bone remodeling mechanism during orthodontic movement, reducing angiogenesis, osteoclast-like cells and Howship's lacunae, thereby, delaying the collagen maturation process in developed bone matrix.

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# Corrosion behavior of self-ligating and conventional metal brackets

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**Objective:** To test the null hypothesis that the aging process in self-ligating brackets is not higher than in conventional brackets.

**Methods:** Twenty-five conventional (GN-3M/Unitek; GE-GAC; VE-Aditek) and 25 self-ligating (SCs-3M/Unitek; INs-GAC; ECs-Aditek) metal brackets from three manufacturers (n = 150) were submitted to aging process in 0.9% NaCl solution at a constant temperature of  $37 \pm 1^\circ\text{C}$  for 21 days. The content of nickel, chromium and iron ions in the solution collected at intervals of 7, 14 and 21 days was quantified by atomic absorption spectrophotometry. After the aging process, the brackets were analyzed by scanning electron microscopy (SEM) under 22X and 1,000X magnifications.

**Results:** Comparison of metal release in self-ligating and conventional brackets from the same manufacturer proved that the SCs group released more nickel ( $p < 0.05$ ) than the GN group after 7 and 14 days, but less chromium ( $p < 0.05$ ) after 14 days and less iron ( $p < 0.05$ ) at the three experimental time intervals. The INs group released less iron ( $p < 0.05$ ) than the GE group after 7 days and less nickel, chromium and iron ( $p < 0.05$ ) after 14 and 21 days. The ECs group released more nickel, chromium and iron ( $p < 0.05$ ) than the VE group after 14 days, but released less nickel and chromium ( $p < 0.05$ ) after 7 days and less chromium and iron ( $p < 0.05$ ) after 21 days. The SEM analysis revealed alterations on surface topography of conventional and self-ligating brackets.

**Conclusions:** The aging process in self-ligating brackets was not greater than in conventional brackets from the same manufacturer. The null hypothesis was accepted.

**Keywords:** Corrosion. Orthodontic brackets. Metal.

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## INTRODUCTION

Metal alloys are frequently used in Orthodontics to fabricate brackets, bands, wires and tubes. These alloys are made of austenitic stainless steel,<sup>1,2</sup> such as AISI 303, 304 and 316L,<sup>3</sup> and have nickel, chromium and iron in their composition.

When exposed to the oral environment, metal orthodontic accessories are subjected to degradation, such as corrosion by pits, fracture due to fatigue, increase in the coefficient of friction or microbiological degradation.<sup>4,5</sup> When the corrosive process occurs, metal ions are released into the oral medium or transformed into oxides.<sup>2</sup>

Self-ligating brackets have been widely used during the last decade by supposing that they have advantages<sup>6</sup> such as reduced treatment time as a result of reduced friction, and a more irregular morphology due to the connection system and larger volume in comparison with conventional brackets. For this reason, it is possible that they are more susceptible to corrosion.

Orthodontic appliance biodegradation is undesirable, and can hinder sliding mechanics,<sup>7</sup> cause reactions of hypersensitivity due to the release of nickel and chromium,<sup>8,9</sup> stain the enamel as a result of incorporating metal ions,<sup>10</sup> or even damage the appliance.<sup>2</sup> In self-ligating brackets, corrosion is also capable of altering the connection system and reducing its effectiveness.<sup>11</sup> In the active ligation system, it may hinder the capacity of pressing the wire into the slot.<sup>11</sup> Conversely, in the passive one, it may hamper opening or closing of the connection system.<sup>12</sup>

The aim of this study was to assess the aging process in conventional and self-ligating metal brackets. To this end, the null hypothesis assumed that the aging process in self-ligating brackets is not greater than in conventional brackets.

## MATERIAL AND METHODS

Table 1 shows the distribution of the analyzed samples. The sample consisted of 150 metal brackets, 75 self-ligating and 75 conventional for maxillary right central incisors, from three different manufacturers (3M Unitek, Aditek and GAC) (25 brackets each). The conventional brackets were Gemini (3M/Unitek, Monrovia, CA, USA), Generus (GAC, Islandia, NY, USA) and Vector (Aditek, Cravinhos, SP, Brazil); whereas the self-ligating brackets were Smart Clip (3M/Unitek), In Ovation R (GAC) and Easy Clip (Aditek).

The 25 brackets of each group were divided into five subgroups, with an equal number of samples each, numbered from one to five.

The brackets of each subgroup were stored in previously sterilized Petri dishes, without coming into contact with one another. They were subjected to corrosion in 20 ml of sterile 0.9% NaCl solution<sup>13,14</sup> for a period of 21 days. The Petri dishes were kept in an incubator (Quimis - Quimis Aparelhos Científicos LTDA., Diadema-SP, Brazil) at an unchanged temperature of  $37 \pm 1^\circ\text{C}$ .<sup>15</sup> Every 7 days  $\pm$  1 hour, the brackets were removed and transferred to another container filled with a new solution.<sup>1,13</sup>

At the end of each experimental time interval (7 days, 14 days and 21 days), the solution remaining in each container was analyzed by atomic absorption spectrophotometry in a Varian spectrophotometer, Model AA-1475 (Varian Indústria e Comércio Ltda., São Paulo/SP, Brazil) with a view to determining their nickel, chromium and iron contents.

At the end of the experiment, five brackets from each group (one from each subgroup) were randomly selected and their surface topography was analyzed by scanning electron microscopy – SEM (Jeol JSM 6460 LV, Japan) and compared with the surface of new brackets.

**Table 1** - Distribution of samples.

| Bracket      | n  | Group | Ligation system | Manufacturer | Reference | Lot        |
|--------------|----|-------|-----------------|--------------|-----------|------------|
| Gemini       | 25 | GN    | Conventional    | 3M / Unitek  | 119-713   | 019329500  |
| Generus      | 25 | GE    |                 | GAC          | 31-212-32 | B479       |
| Vector       | 25 | VE    |                 | Aditek       | 12.32.411 | 100329     |
| Smart clip   | 25 | SCs   | Self ligating   | 3M / Unitek  | 004-302   | 016560600B |
| In Ovation R | 25 | INs   |                 | GAC          | 89-112-00 | B3Y7       |
| Easy clip    | 25 | ECs   |                 | Aditek       | 13.32.011 | 090303     |

SEM was operated at 20 kV, and readouts were taken under 22X and 1,000X magnification. The 22X magnification allowed a complete view of the bracket. The 1,000X magnification was performed at the slot of each bracket with the connection system opened so as to analyze the area for wire insertion. No treatment was performed on the brackets at the end of the experiment in order to prevent any possible oxides, deposited on

the bracket surface as a result of the corrosion process, from being removed. Energy-dispersive X-ray spectroscopy (EDS) was used to identify atypical depositions on bracket surface.

In each group and at each time interval, nickel, chromium and iron concentrations as well as the total amount released during the experiment were statistically assessed. The Kolmogorov-Smirnov test was used to verify the

**Table 2** - Nickel content (PPM) after the different experimental time intervals.

| Nickel release (PPM) |                 |             |             |                 |             |             |                 |             |             |                 |             |
|----------------------|-----------------|-------------|-------------|-----------------|-------------|-------------|-----------------|-------------|-------------|-----------------|-------------|
| 7 days               |                 |             |             | 14 days         |             |             | 21 days         |             |             | Total           |             |
| Group                | Mean $\pm$ SD   | Intra. Sig. | Inter. Sig. | Mean $\pm$ SD   | Intra. Sig. | Inter. Sig. | Mean $\pm$ SD   | Intra. Sig. | Inter. Sig. | Mean $\pm$ SD   | Inter. Sig. |
| GN                   | 0.00            | a           | A           | 0.00            | a           | A           | 0.00            | a           | A           | 0.0 (0.0)       | A           |
| GE                   | 0.14 $\pm$ 0.28 | a           | ABC         | 0.92 $\pm$ 0.03 | b           | B           | 0.68 $\pm$ 0.02 | b           | B           | 1.74 $\pm$ 0.27 | B           |
| VE                   | 0.53 $\pm$ 0.03 | a           | B           | 0.00 $\pm$ 0.01 | b           | A           | 0.00 $\pm$ 0.01 | b           | A           | 0.54 $\pm$ 0.03 | C           |
| SCs                  | 0.11 $\pm$ 0.03 | a           | C           | 0.07 $\pm$ 0.01 | b           | C           | 0.00            | c           | A           | 0.18 $\pm$ 0.01 | D           |
| INs                  | 0.14 $\pm$ 0.01 | a           | C           | 0.39 $\pm$ 0.02 | b           | D           | 0.00 $\pm$ 0.01 | c           | A           | 0.54 $\pm$ 0.03 | C           |
| ECs                  | 2.79 $\pm$ 0.03 | a           | D           | 1.24 $\pm$ 0.03 | b           | E           | 0.00 $\pm$ 0.01 | c           | A           | 4.03 $\pm$ 0.03 | E           |

Identical letters reveal no statistical difference ( $p > 0.05$ ). Intragroup significance - Comparison of the different time intervals in each group with ANOVA test and Tukey post hoc-test. Intergroup Significance - Comparison among the groups in each time interval with Kruskal-Wallis test and Wilcoxon post hoc-test.

**Table 3** - Chromium content (PPM) after the different experimental time intervals.

| Chromium release(PPM) |             |             |             |             |             |             |             |             |             |             |             |
|-----------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 7 days                |             |             |             | 14 days     |             |             | 21 days     |             |             | Total       |             |
| Group                 | Mean ± SD   | Intra. Sig. | Inter. Sig. | Mean ± SD   | Intra. Sig. | Inter. Sig. | Mean ± SD   | Intra. Sig. | Inter. Sig. | Mean ± SD   | Inter. Sig. |
| GN                    | 0.50 ± 0.11 | a           | AB          | 1.03 ± 0.01 | b           | A           | 1.68 ± 0.03 | c           | A           | 3.21 ± 0.12 | AB          |
| GE                    | 0.89 ± 0.10 | a           | C           | 1.29 ± 0.02 | b           | B           | 1.95 ± 0.03 | c           | B           | 4.13 ± 0.10 | C           |
| VE                    | 1.15 ± 0.02 | a           | D           | 1.03 ± 0.05 | b           | A           | 1.95 ± 0.06 | c           | B           | 4.13 ± 0.11 | C           |
| SCs                   | 0.45 ± 0.01 | a           | A           | 0.30 ± 0.03 | a           | C           | 2.05 ± 0.35 | b           | AB          | 2.81 ± 0.33 | D           |
| INs                   | 0.76 ± 0.02 | a           | C           | 1.03 ± 0.08 | b           | A           | 1.42 ± 0.02 | c           | C           | 3.21 ± 0.09 | A           |
| ECs                   | 0.63 ± 0.02 | a           | B           | 1.55 ± 0.03 | b           | D           | 1.16 ± 0.03 | c           | D           | 3.34 ± 0.05 | B           |

Identical letters indicate no statistical difference ( $p > 0.05$ ). Intragroup significance - Comparison of the different time intervals in each group with ANOVA test and Tukey post hoc-test. Intergroup Significance - Comparison among the groups in each time interval with Kruskal-Wallis test and Wilcoxon post hoc-test.

**Table 4** - Iron content (PPM) after the different experimental time intervals.

| Iron release (PPM) |                 |             |             |                 |             |             |                 |             |             |                 |             |
|--------------------|-----------------|-------------|-------------|-----------------|-------------|-------------|-----------------|-------------|-------------|-----------------|-------------|
| 7 days             |                 |             |             | 14 days         |             |             | 21 days         |             |             | Total           |             |
| Group              | Mean $\pm$ SD   | Intra. Sig. | Inter. Sig. | Mean $\pm$ SD   | Intra. Sig. | Inter. Sig. | Mean $\pm$ SD   | Intra. Sig. | Inter. Sig. | Mean $\pm$ SD   | Inter. Sig. |
| GN                 | 0.35 $\pm$ 0.03 | a           | A           | 0.44 $\pm$ 0.03 | b           | A           | 1.02 $\pm$ 0.02 | c           | A           | 1.81 $\pm$ 0.04 | A           |
| GE                 | 0.93 $\pm$ 0.05 | a           | B           | 1.02 $\pm$ 0.02 | b           | B           | 1.28 $\pm$ 0.02 | c           | B           | 3.23 $\pm$ 0.08 | B           |
| VE                 | 1.01 $\pm$ 0.05 | a           | B           | 0.77 $\pm$ 0.04 | b           | C           | 1.02 $\pm$ 0.02 | a           | A           | 2.80 $\pm$ 0.09 | CD          |
| SCs                | 0.00 $\pm$ 0.01 | a           | C           | 0.01 $\pm$ 0.02 | a           | D           | 0.94 $\pm$ 0.02 | b           | C           | 0.96 $\pm$ 0.04 | E           |
| INs                | 0.77 $\pm$ 0.02 | a           | D           | 0.94 $\pm$ 0.02 | b           | E           | 1.01 $\pm$ 0.03 | c           | A           | 2.72 $\pm$ 0.02 | C           |
| ECs                | 1.02 $\pm$ 0.03 | a           | B           | 0.94 $\pm$ 0.02 | b           | E           | 0.94 $\pm$ 0.04 | b           | D           | 2.90 $\pm$ 0.08 | D           |

Identical letters indicate no statistical difference ( $p > 0.05$ ). Intragroup significance - Comparison of the different time intervals in each group with ANOVA test and Tukey post hoc-test. Intergroup Significance - Comparison among the groups in each time interval with Kruskal-Wallis test and Wilcoxon post hoc-test.

sample normality of distribution. As normal distribution was not found, the non-parametric ANOVA test with Tukey post-test were applied for intragroup assessment, whereas the Kruskal-Wallis test with Wilcoxon post-test were applied for intergroup assessment. The data were statistically analyzed using SPSS 17.0 software (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA). The significance level was set at 5%.

## RESULTS

During the experimental period, the release of nickel, chromium and iron metal ions was observed in all groups, except for nickel ion in the GN group, which was not detected at any of the time intervals (Tables 2, 3 and 4).

There was greater release of nickel in the initial period of the experiment, both for conventional and self-ligating brackets, with a trend towards no release of this ion at the end of the experiment ( $p < 0.05$ ). Only group GN and group GE behaved differently with greater release of nickel on the 14<sup>th</sup> and 21<sup>st</sup> days. The

experimental groups revealed a trend towards increasing release of ions, such as chromium and iron, from the first to the third week of the experiment ( $p < 0.05$ ). The only exception was group VE, in which a great amount of iron release was found in the first week. Metal release was similar in self-ligating and conventional brackets from the same manufacturer. Group SCs released more nickel ( $p < 0.05$ ) than group GN after 7 and 14 days, but group GN released more chromium ( $p < 0.05$ ) after 14 days and more iron ( $p < 0.05$ ) at the three experimental time intervals. Group INs released less iron ( $p < 0.05$ ) than group GE after 7 days; and less nickel, chromium and iron ( $p < 0.05$ ) after 14 and 21 days. Group ECs released more nickel, chromium and iron ( $p < 0.05$ ) than group VE after 14 days, but released less nickel and chromium ( $p < 0.05$ ) after 7 days and less chromium and iron ( $p < 0.05$ ) after 21 days.

At the end of the experiment, the SEM analysis revealed that the surface topography of all brackets changed, with signs of aging when compared with the surface of new brackets (Figs 1 to 4).

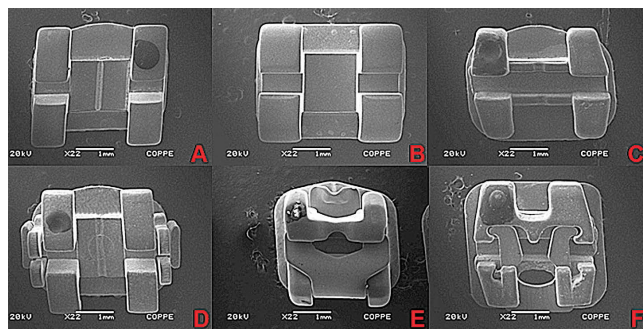


**Figure 1** - Surface topography of new brackets visualized by SEM under 22X magnification. A) GN; B) GE; C) VE; D) SCs; E) INs; F) ECs.

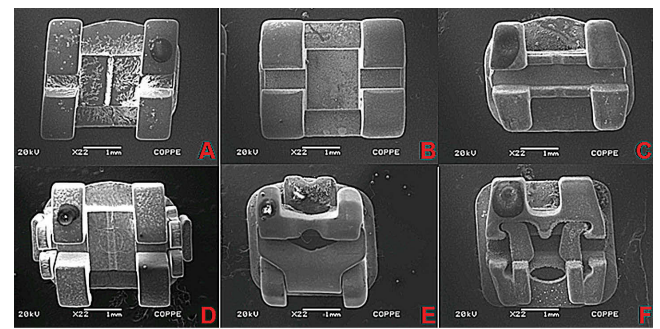


**Figure 2** - Surface topography of brackets visualized by SEM under 22X magnification after 21 days. A) GN; B) GE; C) VE; D) SCs; E) INs; F) ECs.

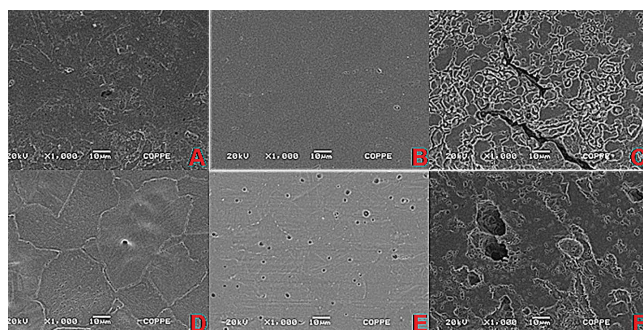


**Figure 3** - Surface topography of new brackets visualized by SEM under 1000X magnification. A) GN; B) GE; C) VE; D) SCs; E) INs; F) ECs.

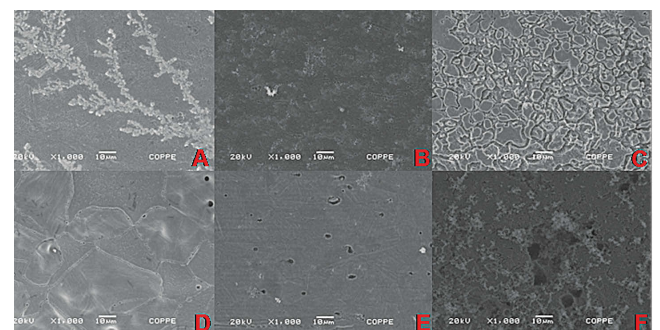


**Figure 4** - Surface topography of brackets visualized by SEM under 1000X magnification after 21 days. A) GN; B) GE; C) VE; D) SCs; E) INs; F) ECs.

## DISCUSSION

Bracket corrosion with consequent release of metal ions during orthodontic treatment may hinder orthodontic mechanics,<sup>2</sup> trigger hypersensitivity reactions with hyperplasia and gingival tissue inflammation,<sup>4,8,9</sup> and contribute to iatrogenic staining of the enamel with the incorporation of metals.<sup>10,16</sup>

A corroded bracket often presents a more irregular surface and can accumulate products resulting from corrosion (Fig 4). Thus, friction between the bracket and wire during sliding mechanics increases, making it necessary to apply force of greater magnitude to overcome the friction and produce physiologic tooth movement.<sup>7,17,18</sup> When excessive force is applied to the bracket, there is loss of mechanical control and increased probability of root resorption.<sup>5,9,19,21</sup>

One of the advantages attributed to self-ligating brackets is the lower degree of friction that the ligation system imposes on the orthodontic wire when compared with conventional tying.<sup>6,22,24</sup> However, if the bracket has an increased corrosion potential, friction also increases,<sup>25</sup> affecting this advantage.

In the present study, SEM analysis under 22X magnification (Fig 2) revealed that, in general, self-ligating brackets showed more areas with altered surface topography due to corrosion, when compared with conventional brackets from the same manufacturer, possibly due to their geometry with larger retentive areas. Thus, brackets in the INs group had a more irregular surface than the brackets in the GE group, while the brackets in the ECs group presented greater alterations in comparison to those in the VE group. The self-ligating brackets of the SCs group and the conventional brackets in group GN did not present significant alterations in their surface topography. Energy-dispersive X-ray spectroscopy (EDS) revealed NaCl deposition on the surfaces of the brackets in group GN.

Analysis of the images obtained by SEM under 1000X magnification (Figs 3 and 4) suggests that new brackets with more irregular surfaces were more susceptible to corrosion. Thus, the brackets in group ECs, which presented a surface topography with deficient smoothness and porosity at the beginning of the experiment, presented a considerably more irregular surface at the end of it. The brackets in group VE also presented considerably altered surfaces at the end of the experiment, due to the formation of oxides. Moreover, the

brackets in group INs, which presented irregularities at the beginning of the experiment, were significantly subjected to pitting corrosion. Quantification of the metal ions released during the experiment corroborates these data. These groups had great release of nickel, chromium and iron ions.

The release of metal ions into the oral environment may trigger hypersensitivity reactions.<sup>4,5,8,9,26</sup> Nickel and chromium are present in the composition of brackets with the goal of increasing resistance to corrosion.<sup>2,4,16,27</sup> These elements are largely responsible for the aforementioned adverse reactions. Nickel is strongly responsible for triggering more allergic reactions than any other metal.<sup>8,26</sup>

Under the conditions of this experiment, the release of nickel was considerably lower than the daily ingestion of this metal through food (300 to 600 µg/day).<sup>13</sup> However, it is worth noting that susceptible patients in contact with small concentrations of this metal are more likely to suffer hypersensitivity reactions.<sup>29</sup>

The oral reaction of allergy to nickel is difficult to diagnose, since its clinical signs and symptoms are similar to those of gingivitis caused by poor oral hygiene. The low number of reports of hypersensitivity to nickel is possibly due to this difficulty in diagnosis. Epidemiological data point towards an incidence of sensitivity to this metal of approximately 20% in the general population.<sup>28,30</sup>

Similarly to other *in vitro* studies,<sup>1,15,31</sup> the release of nickel in this experiment was higher in the first two weeks, with a trend towards no further release during the third week. The exception was group GE which continued to release nickel ions during the last week (Table 2).

Similarly to previous studies,<sup>1,13</sup> chromium and iron ions had a trend towards increasing release throughout the experiment in all groups, except for group ECs (Tables 3 and 4). In this group, there was a greater release of chromium in the second week, and greater release of iron in the first week, although the concentration of these ions remained high at the end of the third week.

Within the limitations and conditions of this experiment, it is reasonable to conclude that metal release was similar in self-ligating and conventional brackets from the same manufacturer.

When self-ligating and conventional brackets from the same manufacturer were compared, group SCs proved to release more nickel ( $p < 0.05$ ) than group GN after

7 and 14 days, whereas group GN released more chromium ( $p < 0.05$ ) after 14 days and more iron ( $p < 0.05$ ) at the three experimental time intervals. Group INs released less iron ( $p < 0.05$ ) than group GE after 7 days and less nickel, chromium and iron ( $p < 0.05$ ) after 14 and 21 days. Group ECs released more nickel, chromium and iron ( $p < 0.05$ ) than group VE after 14 days, but released less nickel and chromium ( $p < 0.05$ ) after 7 days and less chromium and iron ( $p < 0.05$ ) after 21 days.

Metal ions released by metal brackets and bands during orthodontic treatment may be incorporated into tooth enamel, causing iatrogenic color alteration and stains.<sup>10,16</sup> In cases of severe pigmentation, restorative treatment of the vestibular surface of the stained tooth proves necessary.<sup>32,33</sup> Special care must be given to patients with poor oral hygiene, since altered oral environment, with

reduced pH and presence of acidogenic microorganisms potentiates the corrosion of metal accessories. Additionally, enamel demineralization and remineralization processes may influence the incorporation of metals.<sup>4,10</sup>

## CONCLUSIONS

- » The null hypothesis was accepted.
- » The SEM analysis revealed that self-ligating and conventional brackets presented signs of aging.
- » Metal ions release in self-ligating brackets was similar to conventional brackets from the same manufacturer.

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# Class I malocclusion with anterior crossbite and severe crowding

Daltro Enéas Ritter<sup>1</sup>

This article reports the orthodontic diagnosis and treatment planning carried out with a 14-year and 5-month-old female patient with esthetic and functional complaints. She presented an Angle Class I malocclusion, anterior crossbite and severe crowding in both maxillary and mandibular arches, in addition to a lightly concave straight facial profile. Orthodontic treatment did not require extraction. Crossbite was corrected by protrusion of upper teeth, which contributed to alignment and leveling of teeth, in addition to improving the patient's facial profile. The case was presented to the Brazilian Board of Orthodontics and Dentofacial Orthopedics (BBO) as a requirement for the BBO certification.

**Keywords:** Severe discrepancy. Crossbite. Corrective Orthodontics.

## INTRODUCTION

A 14-year and 5-month-old patient, in good health, with controlled allergic rhinitis, showed up for her first appointment. Her mother reported that the patient fell when she was eight years old, and fractured the incisal edge of tooth #41. At that point, the tooth was partially restored and remained as so with neither apical radiolucency nor sensibility until her first orthodontic appointment. The patient avoided smiling and showing her teeth while talking.

Her major complaints comprised lack of space in both maxillary and mandibular arches and anterior crossbite. The patient reported the following: *"I am embarrassed of smiling. I want to have my teeth fixed because they are not aligned, which makes it difficult to bite."* The patient was in the descending pubertal growth spurt curve, 24 months after menarche. Her dental history included good oral hygiene, unchanged tongue position during physiologic movements and no orthodontic treatment.

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

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## DIAGNOSIS

The patient was an adolescent in the residual growth phase.<sup>1</sup> She presented an asymmetrical face, with proportional facial thirds and spontaneous lip seal (Fig 1). She avoided smiling and showing her teeth, which hindered the assessment of spontaneous smile and the amount of tooth exposure at smile. Her forced smile revealed that her upper lip covered the gingival margin of her upper incisors.

The patient had a straight facial profile, with thin, retracted lips in relation to the Nasolabial line (S-UL = -1.0 mm and S-LL = 0 mm).<sup>2</sup>

From a dental point of view, she presented Angle Class I malocclusion (Figs 1 and 2), although her upper and lower canines were in end-to-end anteroposterior relationship. Additionally, she presented severe crowding in the maxillary and mandibular arches (maxillary discrepancy of -10 mm and mandibular discrepancy of -6 mm), and anterior crossbite including #11 and #22. Overjet between #21 and #31 was +3 mm, and -3 mm between #11 and #41. Tooth #41 was fractured and partially restored, given that restoration could not be properly carried out due to lack of space resulting from the malocclusion. Oral hygiene was good.



Figure 1 - Initial facial and intraoral photographs.

Panoramic and periapical radiographs (Fig 3) revealed good root formation for all teeth, absence of apical radiolucencies around tooth #41 as well as absence of bone or dental anomalies. She had unerupted third molars at Nolla's stage 6 (initial root formation).

Cephalometric cephalograms and tracings (Fig 4) revealed a balanced skeletal pattern in the anteroposterior direction between the maxilla, the mandible

and other facial structures ( $ANB = 1^\circ$  and Angle of Convexity =  $-0.5^\circ$ ), with a predominantly horizontal growth pattern and mandibular plane ( $SN-GoGn = 25^\circ$ ,  $FMA = 20^\circ$  and  $Y\text{ Axis} = 54^\circ$ ). Upper and lower incisors were retroclined ( $1-NA = 20^\circ$ ,  $1-NA = 6\text{ mm}$ ,  $1-NB = 17^\circ$ ,  $1-NB = 4\text{ mm}$  and  $IMPA = 83.5^\circ$ ). The aforementioned cephalometric data are shown in Table 1.

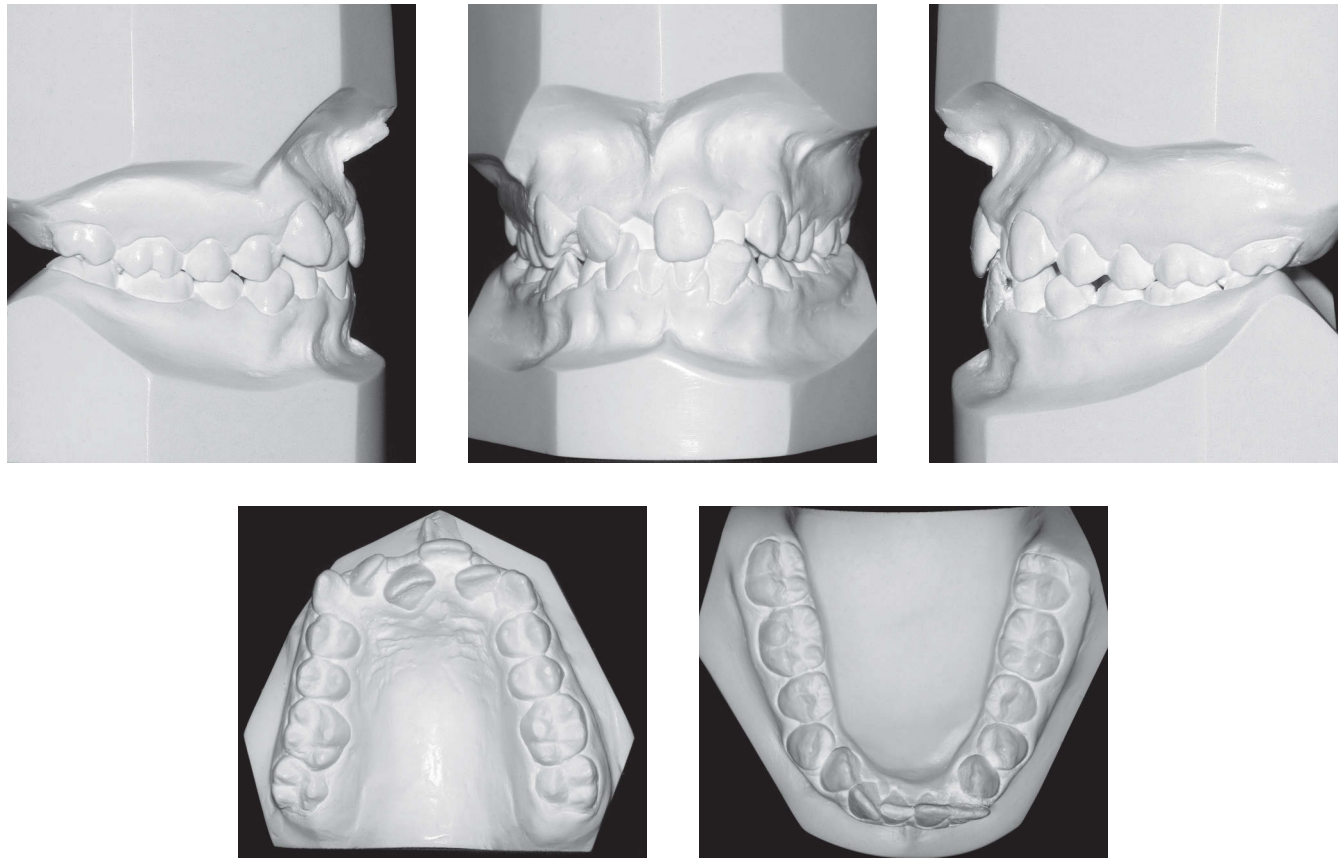


Figure 2 - Initial casts.



Figure 3 - Initial panoramic and periapical radiographs of incisors.

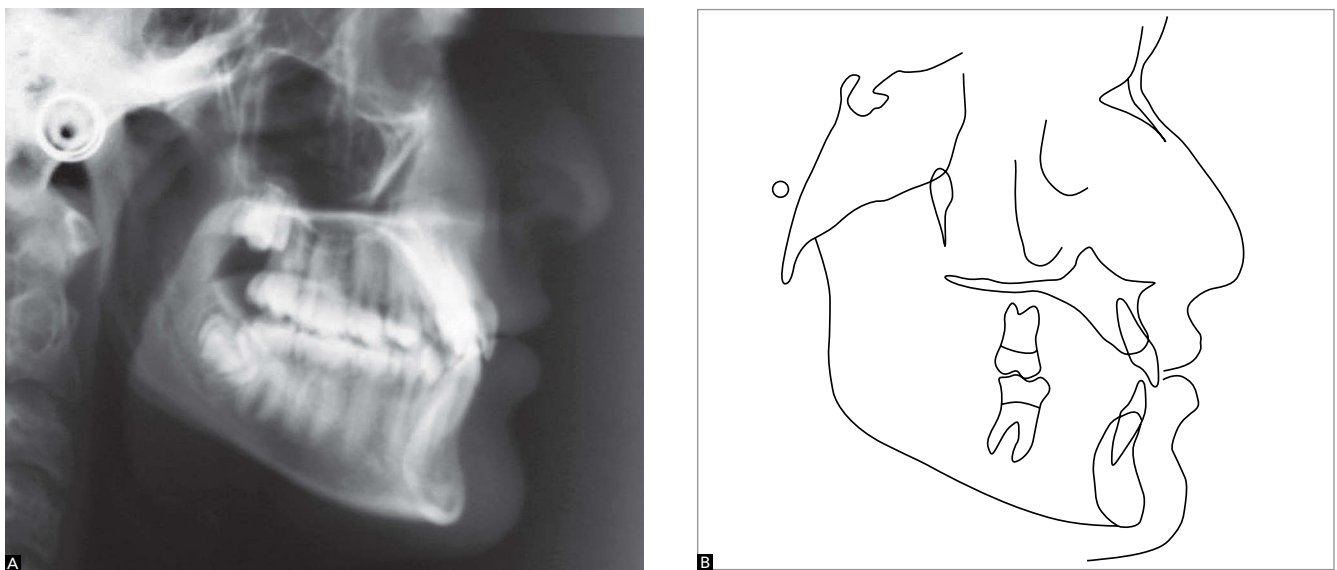


Figure 4 - Initial (A) lateral cephalogram and (B) cephalometric tracing.

## TREATMENT PLAN

The patient had a harmonious and proportional face (front view), but presented a straight profile, which is worrying for a 14-year-old, given that one's profile tends to become more concave with time.<sup>3,4</sup> For this reason, treatment plan avoided extractions

and included protrusion of retroclined incisors, as well as increasing lip support and volume, which resulted in a more convex profile.

The patient presented Angle Class I malocclusion, with anterior crossbite of teeth #11 and #22. Given that her central mandibular and maxillary

incisors were retroclined, treatment plan aimed at obtaining mesio-distal space by means of a fixed orthodontic appliance, providing protrusion of anterior teeth in normal occlusion, increased arch circumference, and protrusion of maloccluded teeth in order to meet normal standards.<sup>5</sup> Negative discrepancy was severe in both maxillary (-10 mm) and mandibular arches (-6 mm). Mandibular canines were visibly retroclined, with reduced distance between canines. Protrusion of maxillary and mandibular incisors was able to solve such negative discrepancy and increase the distance between canines and molars in both maxillary and mandibular arches, particularly in the mandibular canines.

An alternative treatment plan would include extraction of the four first premolars. This treatment option, however, does not allow enough protrusion of incisors and, as a result, does not improve lip support. Moreover, after some years, it would worsen the patient's facial profile.<sup>3,4,6,7</sup>

## TREATMENT PROGRESS

Edgewise 0.022x0.028-in orthodontic brackets were placed in the maxillary arch, except for teeth #11 and 22 (maloccluded). Treatment began with Twist-flex 0.015-in steel archwire placed for initial alignment and leveling. Subsequently, 0.012, 0.014, 0.016 and 0.018-in stainless steel archwires were progressively installed every 30 days, with omega loops mesially adjusted to the first molars. The omega loops were adjusted in 0.05 mm on each side on every orthodontic visit, increasing arch circumference and length, and, as a result, establishing mild and continuous protrusion of incisors with expansion of the arches.

Once the 0.018-in steel wire had been installed, open springs were compressed between teeth #11 and 22 to create space between them. At this point, orthodontic appliance was installed on these teeth. Buccal traction of maloccluded teeth was performed with mild-force elastomeric chains between

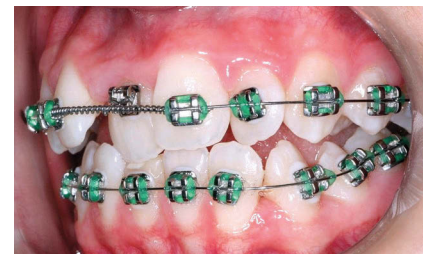
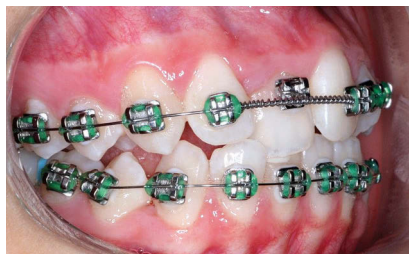


Figure 5 - Intraoral photographs 8 months after treatment onset.

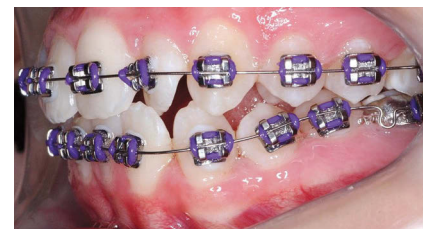
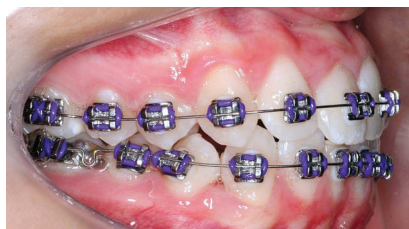


Figure 6 - Intraoral photographs 12 months after treatment onset.

the 0.018" arch and the bonded appliances. At this stage, maxillary incisors were slightly protruded, thus providing enough space to correct the malocclusion (Fig 5). By the time the 0.020" stainless steel wire was installed, the incisors had been satisfactory protruded, thus providing enough mesiodistal space for buccal inclination of #11 and #22 (Fig 6).

After maloccluded teeth were corrected, the appliances of #11 e #22 were replaced and a new 0.014" stainless steel wire was installed for teeth alignment and leveling. Subsequently, 0.016, 0.018, 0.020-in and 0.019x0.025-in stainless steel wires were progressively installed for individual torque control and treatment finishing.

Edgewise 0.022x0.028-in orthodontic brackets were placed in all teeth of the maxillary arch. It is worth noting that on teeth #31, 33 and 43, the appliances were provisionally bonded in a more cervical direction so as to avoid occlusal contact with antagonist teeth. The occlusal bracket wings of teeth #35, 44 and 45 had to be partially worn after bonding due to occlusal interference. Initially, a 0.015-in Twist-flex steel alignment and leveling archwire was installed. Subsequently, 0.012, 0.014, 0.016-in and 0.018-in stainless steel archwires were progressively installed every 30 days, with omega loops mesially adjusted to the first molars. Similarly and concurrently to the maxillary arch, the omega loops were adjusted in 0.05 mm on each side, increasing arch circumference and length, and, as a result, establishing mild and continuous protrusion of incisors.

As protrusion of upper and lower incisors progressed, more space was created for rebonding of teeth #31, 33 and 43 which, as it has been previously mentioned, were initially bonded in a non-ideal position. These teeth were rebonded on an average of three to four times, until their ideal position (in comparison to the other teeth) could be reached. After the 0.019x0.025-in stainless steel rectangular archwire was installed, with it acting over the torques and establishing correct intercuspation, the appliance was removed.

Retention consisted of a wraparound removable appliance in the maxillary arch, used full-time (except for meals and oral hygiene) during six months, 12 hours per day during the following six months and while sleeping during the last six months

of retention. After a retention period of a year and a half, the patient was advised to use the maxillary retainer two nights a week while sleeping for an indefinite period of time.

In the mandibular arch, a 0.020-in stainless steel wire intercanine bar was installed to ease incisors and canines interproximal space. This retainer was used for an indefinite period of time. Third molars were extracted six months before treatment completion.

## RESULTS

At treatment completion, patient's self-esteem had significantly improved. Good facial proportions were observed in frontal view, with patient's profile improved due to an increase in lip volume as a result of incisor protrusion (Fig 7). Horizontal residual mandibular growth was greater than expected, given that menarche had occurred one year and a half before treatment onset. If incisor protrusion had not been planned, patient's profile would be clearly concave. Protrusion allowed patient's profile to favorably develop with age.<sup>6,7</sup>

Molar and canine relationships were obtained in key to occlusion (Figs 7 and 8). Anterior crossbite and discrepancy of upper and lower models were corrected by protrusion of upper and lower incisors and mild expansion of the arches (Tab 2). The distance between lower molars increased in 2 mm, while the distance between upper molars increased in 3 mm during treatment. As for the distance between lower canines, it increased in 5 mm, whereas between upper canines, it increased in 1.5 mm. The greater increase in distance between lower canines was a result of accentuated lingual inclination of teeth #33 and 43, which was corrected during treatment.<sup>8</sup> The average distance between lower canines in untreated patients is 25 mm, whereas in the case reported herein it was of 22 mm. Normal overjet and overbite were obtained with anterior disocclusion guides on the incisors, and lateral disocclusion guides on right and left canines.

Final panoramic radiograph revealed root parallelism, whereas periapical radiographs revealed absence of root resorption (Fig 9). During treatment, restoration of tooth #41 was recommended. However, the dentist advised the patient to wait for treatment completion in order to have such procedure carried out. At treatment completion, tooth #41

presented apical radiolucencies, as revealed by the final periapical radiograph, and the patient was referred to a specialist for endodontic treatment and restoration of tooth #41, all of which were carried out one month after the orthodontic appliance had been removed. Radiographic control taken six months afterwards revealed periapical repair (Fig 10).

Final cephalometric tracings and cephalogram (Fig 11, Tab 1) highlighted that, by the end of treatment, maxillary incisors were in increased protrusion ( $1-NA = 36^\circ$  and  $1-NA = 10$  mm), although clinically appropriate, whereas mandibular incisors were well positioned ( $1-NB=25^\circ$ ,  $1-NB=6$  mm and  $IMPA=92^\circ$ ).

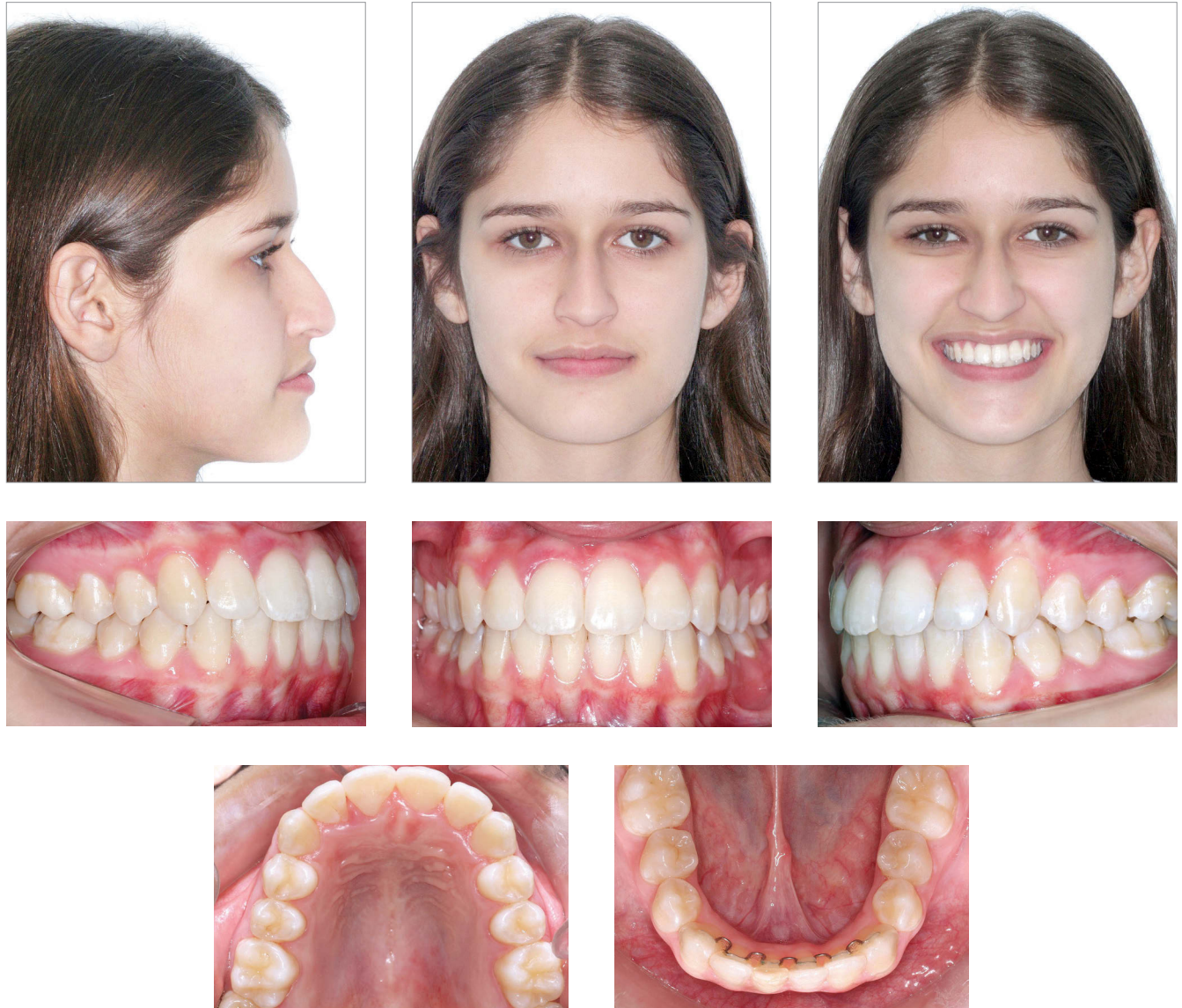


Figure 7 - Initial facial and intraoral photographs.

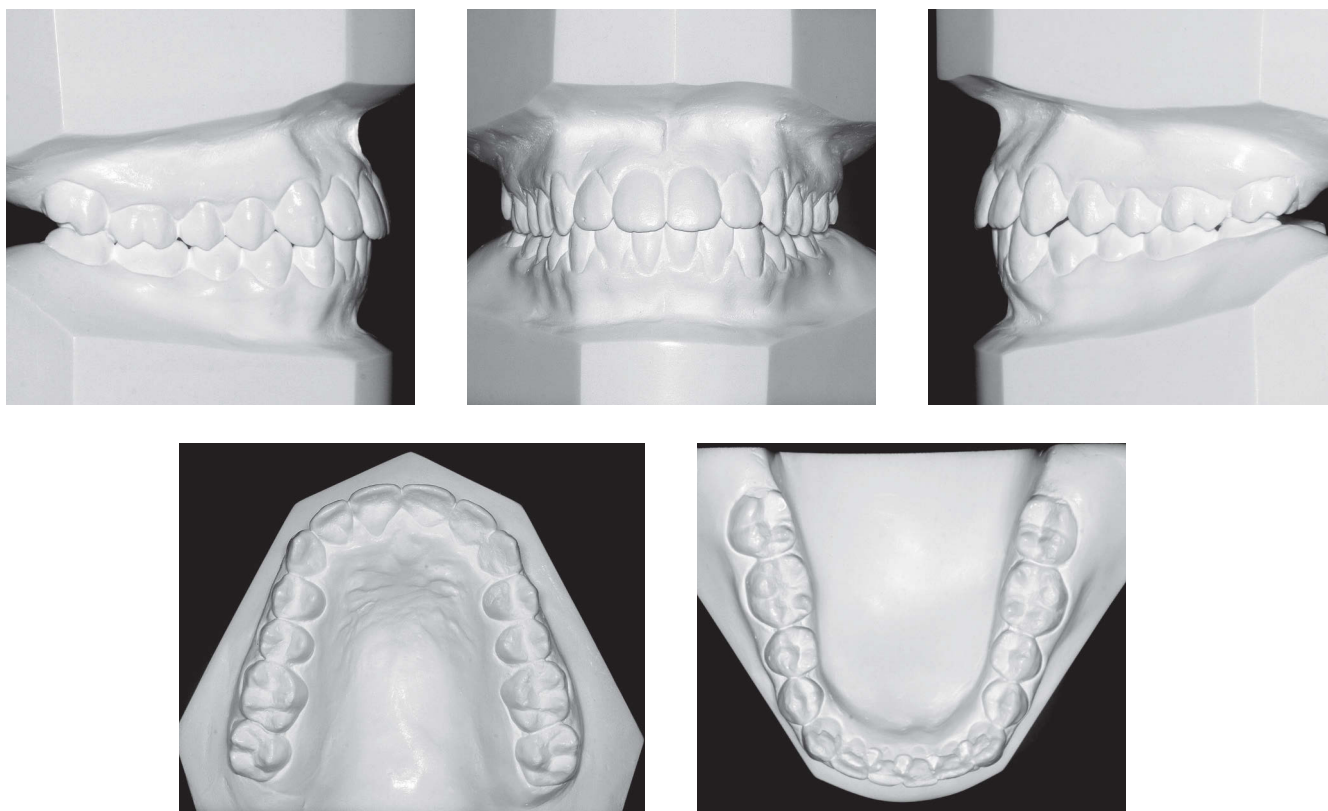


Figure 8 - Final casts.

At treatment completion, the mandible was more anteriorly positioned in relation to the maxilla, with  $ANB = -1^\circ$  and angle of convexity  $= 0.5^\circ$ , both clinically acceptable. The mandibular plane revealed mild anticlockwise movement, observed by a reduction in the mandibular plane angles (SN-GoGn and FMA) and Y Axis.

Cephalometric tracing superimposition revealed that, during treatment, mandibular growth in the horizontal direction of the maxilla was greater (Fig 12), which could be explained by the reduced anterior movement of point A in relation to point B, showing little maxillary growth in relation to the

maxilla as a result of the buccal inclination of maxillary incisors. An increase in the inclination of maxillary incisors, with palatal root movement as a consequence, may have been influenced by the posterior positioning of point A, giving the false impression of insufficient maxillary growth.

### FINAL CONSIDERATIONS

The results were obtained as planned: excellent facial esthetics, anterior teeth in normal occlusion and improvements in alignment and leveling. The patient demonstrated to be satisfied with the results, which improved her self-esteem.

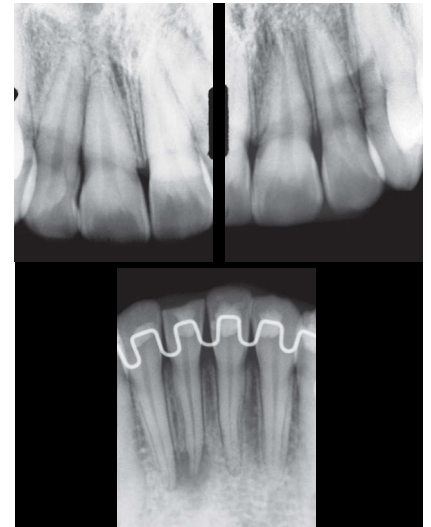


**Figure 9** - Final panoramic and periapical radiographs of incisors.

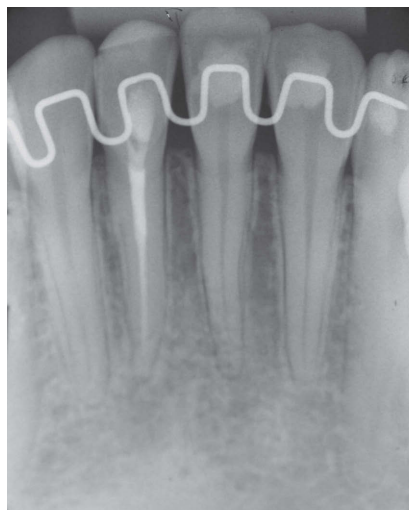


**Figure 10** - Control periapical radiograph of tooth #41 six months after endodontic treatment.

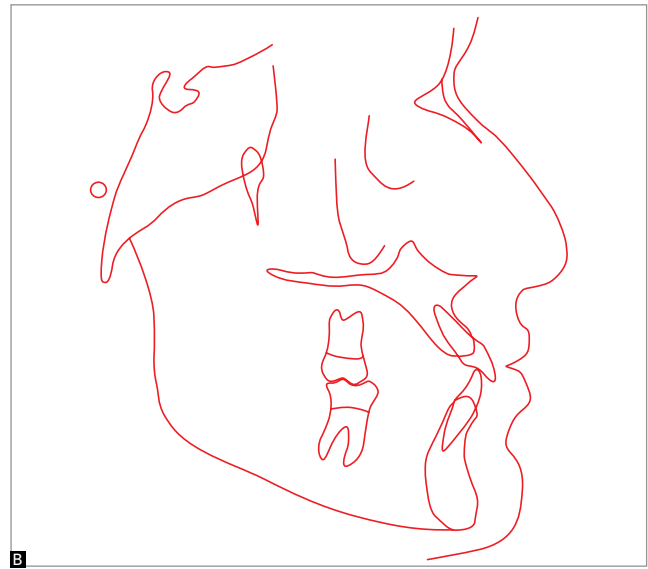
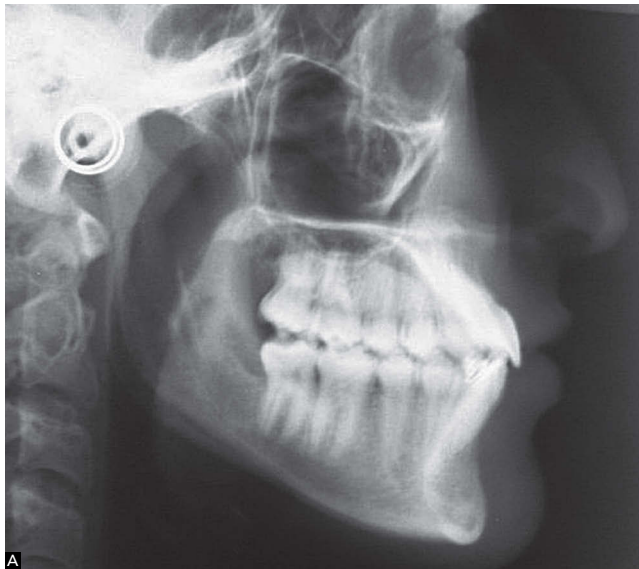


**Figure 11** - Final (A) lateral cephalogram and (B) cephalometric tracing.

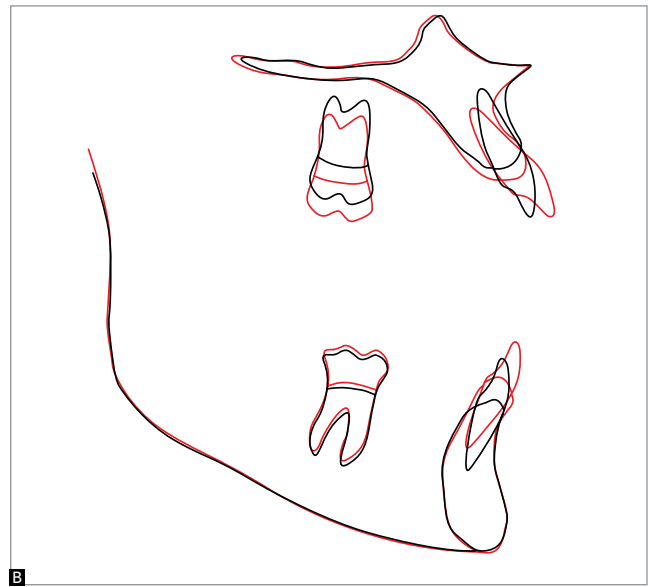
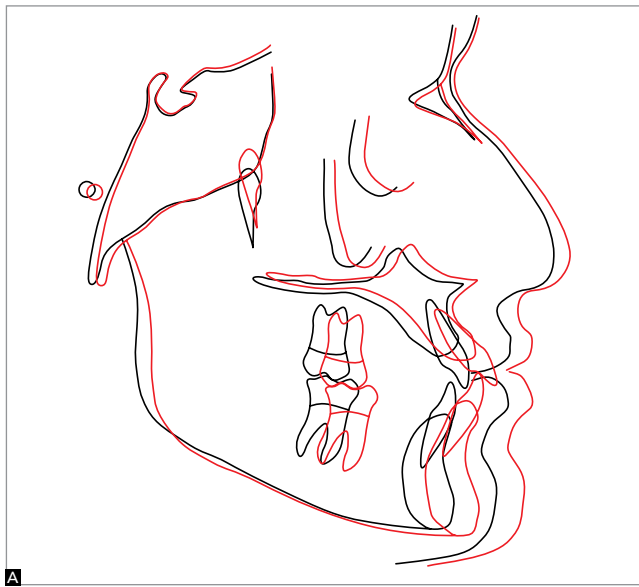


**Figure 12** - Initial (black) and final (red) cephalometric tracing total (A) and partial (B) superimposition.

Table 1 - Cephalometric measurements.

|                  | Measurements              |            | Normal | A       | B       | Dif. A/B |
|------------------|---------------------------|------------|--------|---------|---------|----------|
| Skeletal pattern | SNA                       | (Steiner)  | 82°    | 87°     | 87°     | 0        |
|                  | SNB                       | (Steiner)  | 80°    | 86°     | 88°     | 2        |
|                  | ANB                       | (Steiner)  | 2°     | 1°      | -1°     | 2        |
|                  | Angle of convexity        | (Downs)    | 0°     | -0.5°   | -4.5°   | 4        |
|                  | Axis Y                    | (Downs)    | 59°    | 54°     | 53°     | 1        |
|                  | Facial angle              | (Downs)    | 87°    | 94.5°   | 97°     | 2.5      |
|                  | SN-GoGn                   | (Steiner)  | 32°    | 25°     | 23°     | 2        |
|                  | FMA                       | (Tweed)    | 25°    | 20°     | 17.5°   | 2.5      |
| Dental pattern   | IMPA                      | (Tweed)    | 90°    | 83.5°   | 92°     | 8.5      |
|                  | 1.NA                      | (Steiner)  | 22°    | 20°     | 36°     | 16       |
|                  | 1-NA                      | (Steiner)  | 4 mm   | 6 mm    | 10 mm   | 4        |
|                  | 1.NB                      | (Steiner)  | 25°    | 17°     | 25°     | 8        |
|                  | 1-NB                      | (Steiner)  | 4 mm   | 4 mm    | 6 mm    | 2        |
|                  | 1.1 – Interincisal angle  | (Downs)    | 130°   | 142°    | 120°    | 22       |
|                  | 1-APo                     | (Ricketts) | 1 mm   | 2.5 mm  | 5 mm    | 2.5      |
| Profile          | Upper lip – Line S (S-UL) | (Steiner)  | 0 mm   | -1.0 mm | -1.0 mm | 0        |
|                  | Lower lip – Line S (LL-S) | (Steiner)  | 0 mm   | 0 mm    | 0 mm    | 0        |

Table 2 - Measurements of transversal distances of the dental arches (mm).

| Cast / phase measurements      | A     | B       | Dif. A/B |
|--------------------------------|-------|---------|----------|
| Distance between lower canines | 22 mm | 27 mm   | 5 mm     |
| Distance between lower molars  | 43 mm | 45 mm   | 2 mm     |
| Distance between upper canines | 36 mm | 37.5 mm | 1.5 mm   |
| Distance between upper molars  | 49 mm | 52 mm   | 3 mm     |

In spite of the anterior displacement of the mandible being greater than expected, patient's profile remained straight as a result of protrusion of incisors, which provided lip support and volume with excellent esthetics. Key to occlusion was obtained for molars and canines with ideal occlusion guides.

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# Segmented arch or continuous arch technique?

## A rational approach

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This study aims at revising the biomechanical principles of the segmented archwire technique as well as describing the clinical conditions in which the rational use of scientific biomechanics is essential to optimize orthodontic treatment and reduce the side effects produced by the straight wire technique.

**Keywords:** Orthodontics. Corrective Orthodontics. Biomechanics.

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

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## INTRODUCTION

Specialists in Orthodontics, particularly beginners, often have many questions in mind: Which technique should be used? What is the best bracket prescription? Which is the most recommendable type of bracket: conventional or self-ligating? When are the straight archwire and segmented mechanics techniques best recommended?

Making an accurate diagnosis of the changes observed in patients is necessary. Likewise, an effective treatment plan performed within a shorter period of time, with as little injuries to protective and supporting tissues as possible, is also essential. Thus, regardless of the type of bracket, prescription, technique or slot, recommending the most appropriate treatment is what really matters. For this reason, knowing the principles on which each technique is based on, as well as its limitations, is essential. For instance, treating a clinical case of a maxillary canine in infralabioversion by means of the straight archwire technique used to level the tooth is a harmful procedure for adjacent teeth. Canine extrusion would occur regardless of the type of bracket, whether conventional or self-ligating, however, it would be followed by undesired intrusion and failure of the lateral incisor and first premolar (Fig 1). Many authors claim

that such undesired effect would not result in any further issues, given that it would be solved with intermaxillary rubber bands, arch bends or wire progression. However, it results in a side effect of which solution demands extra treatment time, results in increased biological damage and potential root resorption. Thus, in this case, it is incongruous to use straight wires to level a canine, regardless of the type of bracket.

Conversely, a complementary technique can be used to employ such procedure without producing further side effects on adjacent teeth. With the aid of the segmented arch technique (SAT) and after healing of the anchorage unit, only the canine is extracted by a cantilever or a rectangular loop (Fig 2). Differently from the conventional techniques, which normally use an arch made of one single alloy, connecting all brackets and adjacent tubes; the SAT uses arch segments connected to each other, but not necessarily connected to brackets and adjacent tubes. This allows a combination of wires made of different alloys, dimensions and hardness to be used. Rigid and thick archwires can connect groups of teeth into anchorage units, whereas flexible archwires are used to exert forces between these units.<sup>1</sup>

After employing the segmented mechanics, treatment can be conventionally performed with straight wires.

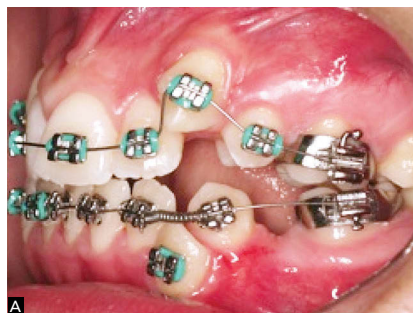


**Figure 1** - A) Straight wire mechanics used for canine extrusion. B) Note the side effects on the lateral incisor and first premolar, which made the conditions of the case worse.

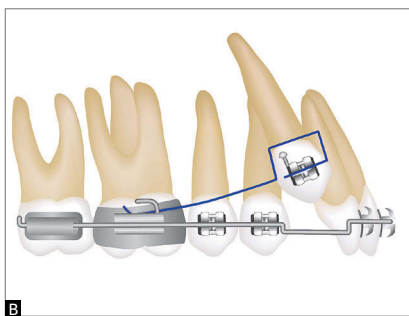
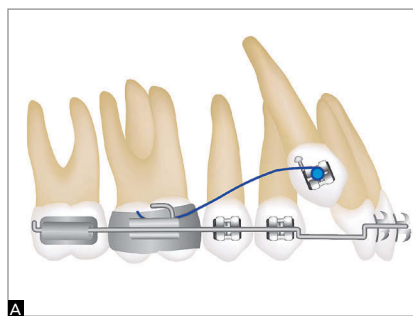


**Figure 2** - Cantilever (A) and rectangular loop (B) for canine extrusion.

Thus, this article aims at discussing how SAT can aid orthodontists to solve specific cases by means of a rational approach.

## PRINCIPLES BEHIND THE SEGMENTED ARCH TECHNIQUE

SAT was developed by Dr. Charles Burstone in 1962. It consists of a sequence of orthodontic procedures based on the mechanical principles of Mechanics. Thus, in order to fully understand the principles behind it, it is essential to comprehend the following concepts: horizontal force, torque, moment of force, moment of torque, equivalent system of forces, moment-to-force ratio and load/deflection ratio.<sup>2</sup>

Horizontal force is a vector able to overcome inertia, thus changing the position of the moving body. Torque refers to two noncollinear, coplanar forces of same intensity, but opposite direction. A body subjected to torque tends to rotate about an axis, in which the center of resistance (CRes) coincides with the center of rotation (CRot), causing a tooth to go through pure rotation.<sup>1,2,3</sup>

Nevertheless, whenever a horizontal force is applied to a tooth and this force bypasses the CRes, the latter produces a rotational movement known as “moment of force”. In this case, the crown moves in one direction, while the root moves in the opposite direction, with the CRot more apical towards the center of resistance. This movement is known as uncontrolled tipping (Fig 3).<sup>1,2,3</sup>

On the other hand, should the force go exactly through the CRes, this tooth will move by translation (Fig 4), in which case the CRot is in the infinite. However, it is worth mentioning that it is extremely difficult to have force going exactly through the CRes. Therefore, in order to achieve a translatory movement, it is important to establish an equivalent system of forces that is applicable to a bracket. In other words, a different system of forces that produces the same effect on the CRes of a tooth, even if applied to the crown.<sup>1,2,3</sup>

Didactically speaking, to increase our understanding on the subject, it has been established that the distance from a canine bracket to its CRes (approximately  $\frac{1}{3}$  of the distance from the alveolar crest to the apex, more cervically) is of 10 mm (in normal clinical conditions). In these cases, if a horizontal force of 100 gf is applied to the bracket, the moment of force

( $M = F \times d$ ) equals 1000 gf.mm. Therefore, the tooth moves by uncontrolled tipping. However, biomechanically speaking, by means of an equivalent system of forces, it is possible to move a tooth by translation, even if force is applied to the brackets (Fig 5).<sup>1,2,3</sup>

In order to make such a movement, it is necessary to expel the moment of force, letting the horizontal force act. To this end, it is necessary to make a gable bend in order to create a torque in the bracket slot, producing a moment of -1000 gf.mm (in the opposite direction of the moment of force). That moment is known as moment of torque. Thus, the moment of force and the moment of torque are neutralized, and the horizontal force will be the only one acting in the tooth, promoting tooth translation (Fig 5). The ratio between the moment of torque (-1000 gf.mm) and the horizontal force (100 gf) is known as moment-to-force ratio (MF), and it determines the position of the CRot of the tooth, which, in this case, is 10/1 (absolute value). The MF ratio is the scientific basis to establish differential movements by means of an equivalent system of forces<sup>1,2,3</sup> (Fig 5). Retraction of anterior teeth is a classic clinical example. Whenever orthodontic archwires exert forces onto brackets, anterior teeth undergo movement of retraction (horizontal force) and uncontrolled tipping (moment of force). In order to maintain correct axial tipping, it is necessary to apply a moment so as to oppose such tendency towards tipping (moment of torque) by means of incorporating vestibular torque of the crown (to brackets and/or archwires). Ideally, should there be a balance between the moment of torque and the moment of force (tendency towards uncontrolled tipping), a moment of retraction is established by translation.

The concept of load/deflection ratio (LF) is also key to understand SAT. Orthodontic wire tension-deformation charts show that such ratio is characterized by the slope of the line during the elastic phase of the wire, which corresponds to Hooke's law (Fig 6). Thus, clinically speaking, it is characterized by the amount of load (force) that is lost when the appliance is unloaded (deactivated).

In other words, the more bended a line is (for instance, a steel wire), the more force is lost for each millimeter of deactivation. On the other hand, beta-titanium wires ( $\beta$ -Ti) present a lower slope of the line, which results in a minor loss of force during deactivation, i.e., a lower LF ratio.

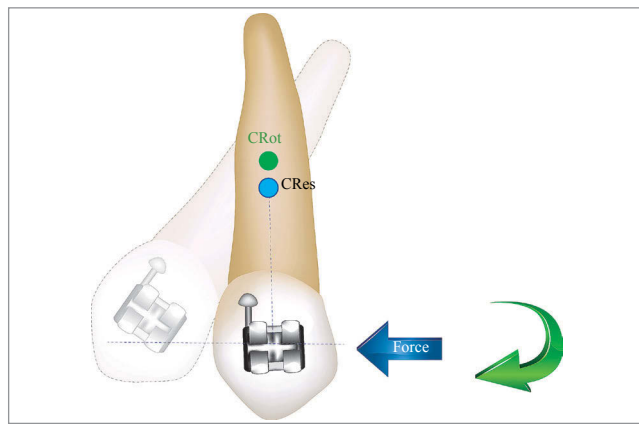


**Figure 3** - Uncontrolled tipping with force bypassing the CRes. Note that the CRot is apically displaced. (Source: adapted from Almeida<sup>31</sup>).



**Figure 4** - Translatory movement with force going exactly through the CRes. Note that the CRot is in the infinite. (Source: adapted from Almeida<sup>31</sup>).

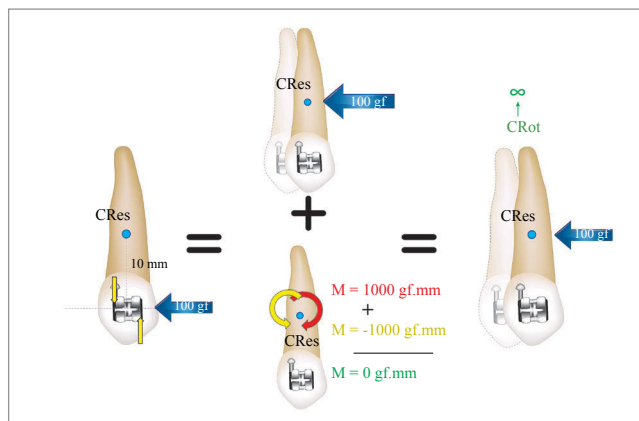


**Figure 5** - Example of an equivalent system. Canine subjected to a 100-gf force (blue arrow) 10 mm away from its CRes, with a 1000-gf.mm torque moving by translation. In red, the moment of force. In yellow, the moment of torque; and in green, the moment resulting from the CRes (Source: adapted from Almeida<sup>31</sup>).

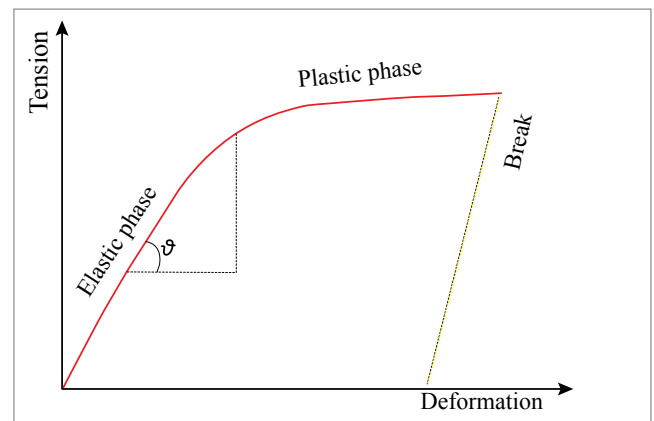


**Figure 6** - LF ratio of a wire is calculated by the slope of the line during its elastic phase.

Low LF ratio wires are ideal for segmented mechanics, given that they tend to keep satisfactory levels of force during system deactivation, proving frequent follow-ups or continuous adjustments to be unnecessary.<sup>4,5</sup>

Additionally, an increase in the distance between brackets, as a result of segmentation and the use of auxiliary tubes, increases the points of force application and allows more predictable mechanics to be carried out. Furthermore, increased distances allow springs to have their LF ratio decreased, which results in greater activations and a lower number of adjustments. Such increase in the distance between brackets allows accessories to be safely positioned and activations to be more safely performed in comparison to conventional mechanics.<sup>1</sup>

The advantage of not connecting adjacent brackets (with greater distance between them) can be used to selectively dissipate forces and moments. Differently from straight wire mechanics, in which reactive forces are dissipated around points of force application as a result of adjacently connecting the brackets, in SAT, the site where the reaction will be dissipated can be previously selected. Canine extrusion reactive forces and moments can, for instance, be dissipated in molars instead of incisors and bicuspsids.<sup>1</sup>

In addition to that, the new metal alloys allowed excellent forces to be produced without changing the transverse section, in which case the concept of variable module was introduced to Orthodontics.

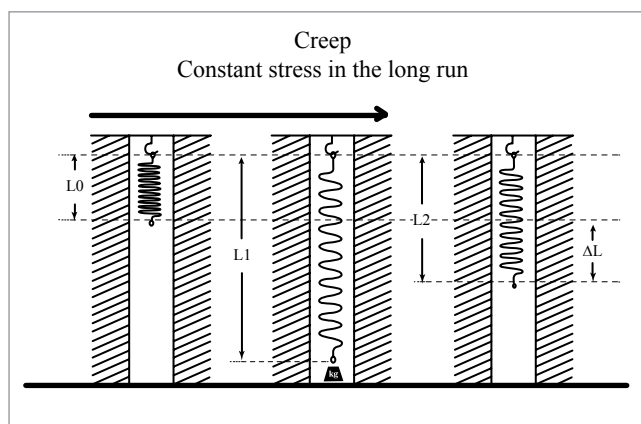


Figure 7 - Example of creep (Source: adapted from Caldas et al<sup>4</sup>).

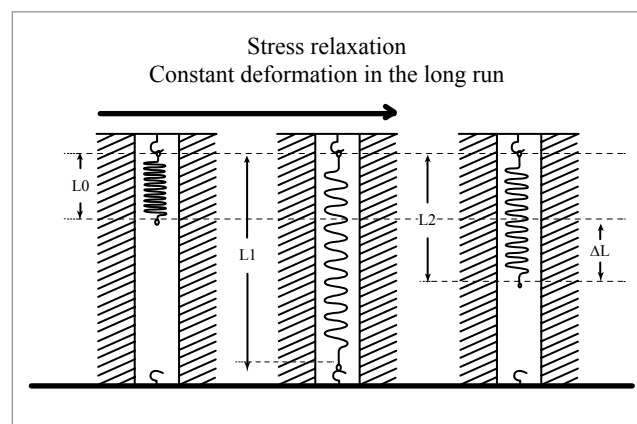


Figure 8 - Example of stress relaxation.

The advantages of the variable module include a better control of tooth movement as a result of opting for rectangular wires since the beginning of treatment, as well as reduction in the number of archwires used during mechanics and fabrication of appliances that produce horizontal force of less magnitude and low LF ratio. In this context,  $\beta$ -Ti wires have become indispensable for producing biological tooth movement through ideal forces, in which case these wires are chosen for SAT.<sup>2</sup>

$\beta$ -Ti alloy, commercially known as TMA or titanium molybdenum alloy (Ormco Corporation, Glendora, USA), presents the properties of a “higher quality” wire, for instance: high springback properties, lower hardness values in comparison to steel, high formability and weldability with no reduction in resilience, and resistance to corrosion. It has higher springback properties in comparison to stainless steel and it is able to be deflected twice as much without permanent deformation. Additionally, it releases forces that correspond approximately to half of the forces released by steel alloys under similar activation, which causes its LF ratio to be approximately half of the stainless steel ratio.<sup>6</sup>

However, the majority of clinicians do not remember that, in most types of material, plastic deformation occurs if tension exceeds its limit of elasticity,<sup>5</sup> in other words, that plastic deformation is also time-dependent.<sup>5,7</sup> Whenever a given material is

constantly subjected to load or stress within its elastic limit, it may undergo progressive deformation known as creep.<sup>5,7</sup> From a microscopic prospect, creep in metals results from displacements in the crystal structure of matter. Such microscopic phenomenon can be experimentally considered as an increase in deformation associated with constant stress (Fig 7) or an increase in stress associated with constant deformation (stress relaxation) (Fig 8). Creep depends on the intensity of stress and temperature, given that high tension and temperature favor displacement. In Engineering, creep in metals is only considered when the temperature accounts for at least 30% of the material melting point, given that structural components often undergo high tension.<sup>5,7</sup>

As for orthodontic springs, acute bends are generally employed to shape the wire. Such bends centralize stress, producing unstable spacing and displacement in the crystal structure of high tension sites.<sup>5</sup> Orthodontists have tried to overcome such problem by thermally treating orthodontic stainless steel appliances so as to rearrange the crystal structure and, as a result, relieve residual tension.<sup>8</sup> The Bauschinger<sup>2</sup> effect is also another strategy commonly employed. It consists in overactivating the wire and simulating activations until the wire is properly shaped for applying the system of forces.

Such progressive deformation, as a result of structural stress relief, has been recently proved by mechanical

trials conducted with  $\beta$ -Ti T-loop springs previously activated by bends, in which case reduction in force and moments of 15.5 and 17.15%, respectively, were observed within the first 24 hours. In clinical practice, applying an acute bend to shape an orthodontic appliance may cause the latter to loose and, as a consequence, change its system of forces under constant deformation. In these cases, the appliances must be overactivated or the acute bend must be replaced by curvature activation, i.e., gradual activation without significant sites of stress.<sup>8</sup>

Another fact that should be carefully assessed is the interchangeable use of  $\beta$ -Ti wires that are available on the market. Once the patent for the first commercial brand of  $\beta$ -Ti expired (TMA,OrmcoCo., Glendora, USA), the use of  $\beta$ -Ti alloys drastically expanded with a wide range of price and quality.<sup>9</sup> In spite of the large number of brands available, only a few researches have been conducted to investigate the properties of this type of wire.<sup>10,11,12</sup> Those researches compared the mechanical properties of  $\beta$ -Ti alloys by means of traction tests<sup>11,12</sup> or 3-point flexural tests<sup>10</sup> in straight wire segments. This may not demonstrate how different  $\beta$ -Ti alloys behave when bends are placed in the wires or when more elaborate designs are chosen (springs, loops, cantilevers, etc.). A recent research conducted with four different  $\beta$ -Ti wires (TMA [Ormco Co.], Beta Flexy [Orthometric Imp. Exp. Ltda, Marília/SP, Brazil], Beta III Wire [Morelli Ortodontia, Sorocaba/SP, Brazil] and Beta CNA [Ortho Organizers, INC., San Marcos, USA]) revealed that the wires produced different systems of force when used in the form of a more elaborate design (T-loop spring) due to the fact that each one of the wires responded differently when a bend was created. TMA and Beta CNA revealed more consistent MT ratios during trials. Such results do not mean that the other types of wire must not be clinically used; although they need to be employed with a different approach.<sup>9</sup>

Thus, SAT, as it has been previously stated, involves several mechanical concepts and particularities that must be well understood by those employing it. Its application is rather useful for performing a rational orthodontic treatment. However, it is recommended for specific cases, i.e., to treat specific conditions such as canine extrusion and retraction, deep bite correction, molars uprighting and occlusal plane correction.

## CANINES EXTRUSION

Maxillary canines are often impacted due to being the last teeth to erupt in the oral cavity, having a complex eruption path, or due to the lack of space for appropriate positioning in the dental arch.<sup>13</sup>

In these cases, orthodontic traction may be carried out by means of SAT with the aid of a cantilever or a rectangular loop. As it has been previously mentioned, the use of mechanics with continuous wire, regardless of the type of bracket, produces several side effects on teeth adjacent to the canine. For this reason, it must be avoided. Therefore, by means of SAT, the desired movement is achieved when force is directly applied to the mal-positioned/impacted tooth, while reactive force is dissipated or controlled in the posterior anchorage unit as a result of an increase in the number of teeth joined to the segment and/or the use of an anchorage appliance.

Clinically speaking, both appliances are feasible and effective. However, biomechanically speaking, they present peculiar characteristics that need to be well understood by the clinician. A cantilever can be described as a segment of a stainless steel 0.017 x 0.025-in wire or a  $\beta$ -Ti wire inserted inside a bracket or tube in the reactive member, tied to the opposite end by means of contact point in the active member (impacted or mal-positioned canine). Therefore, the wire is not inserted into the bracket slot where movement is desired. Should the force produced by an activated cantilever (ranging from 40 to 60 gf) be directed along the CRes of the tooth, it will produce a translatory movement. Should it bypass the CRes of the tooth (in most cases, it is applied to the crown), it will result in a rotational tendency of force due to the moment of force established (Fig 9).

Conversely, given that the wire has been inserted inside the bracket slot or tube, a force of equal intensity and opposite direction is observed in the reactive member. Similarly, a torque is produced inside the appliance when the moment arm of the activated cantilever is tied to the tooth to be moved. Such torque produces movement that, in association with force, must be restricted or reduced to nothing by reinforcing the anchorage of the reactive member (for instance, by using a palatal bar), so as to avoid side effects on the mechanics. Therefore, a cantilever is a statically determined system, characterized by force and moment of force in the active member, whereas it is characterized by force of similar

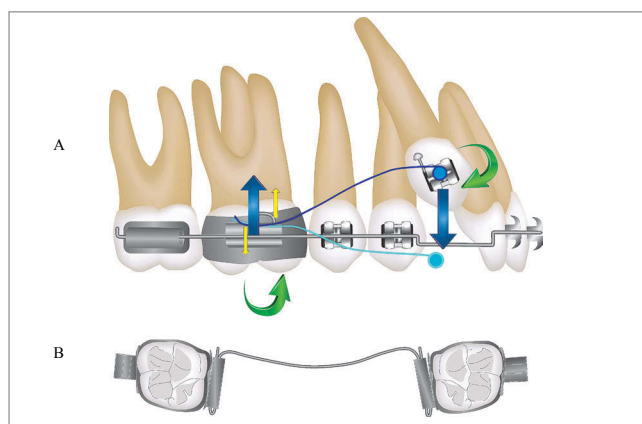


**Figure 9** - A) System of forces produced by a cantilever (statically determined system). This system also reveals a tendency towards palatalization of #13 with force going in the vestibular direction of CRes. B) Palatal bar used to control any undesired effects on the anchorage unit.

intensity, but opposite direction, and moment of torque in the reactive member. Such system provides a system of forces that can be easily visualized and predicted during the process of deactivation (Fig 9).

A rectangular loop is recommended for tridimensional control of a tooth with more severe positioning anomalies. It may be fabricated with stainless steel 0.017 x 0.025-in wire or  $\beta$ -Ti wire between 6 and 7 mm in the cervical-occlusal direction, and between 8 and 10 mm in the mesiodistal direction.<sup>13</sup> Unlike a cantilever, a rectangular loop is inserted inside the bracket slot of an active member. Therefore, in this case, in addition to force (moment of force), a moment of torque is also established as a result of inserting the wire inside the slot. In the reactive member, the system is similar to a cantilever. This system is statically undetermined, given that during deactivation, the system of forces may be little predictable due to changes in tooth positioning (Fig 10).

Thus, it is recommended that a cantilever be used in buccally or lingually placed impacted canines that need to be lingually or labially repositioned, respectively. A cantilever allows a system of forces to be applied in the desired direction, which may be determined by the method of preactivation. A cantilever may be replaced by a rectangular loop, provided that the crown of the canine is apparent and its movement may be three-dimensionally controlled until correct positioning is achieved in the dental arch.<sup>13</sup>

## CANINE RETRACTION

Canine retraction for resolution of previous crowding is a clinical condition that largely favors the use of

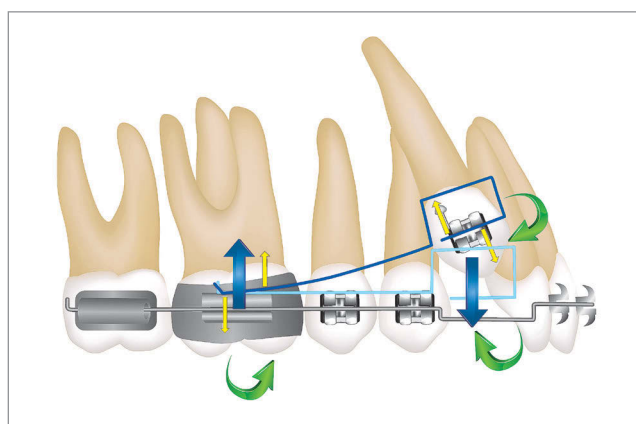


**Figure 10** - System of forces produced by a rectangular loop (statically undetermined system). The activated rectangular loop (light blue) must be adjusted so as to determine the final position of the tooth. When inserted into the slot (dark blue), its deactivation will move the tooth in the previously established position.

SAT before straight wires are used. Should the orthodontist choose to perform mechanics with straight wires avoiding buccal tipping of incisors, straight wires will be progressively used without including the incisors in the arch. Canine retraction begins with an E-arch (rectangular steel wire). Another option would be passive E-arch in the posterior region and canine, which would allow retraction since the first month of treatment.

Another relevant point is mesiodistal tipping of canines, in which case three situations should be considered: canine mesially tipped with the apex more distally placed than the cuspid tip; upright canine with root apex and cuspid tip virtually occupying the same position in the mesiodistal direction; distally tipped canine with the apex more mesially placed in relation to its cuspid (Fig 11). Using straight wires for cases of mesial tipping and upright teeth favor the resolution of crowding and canine retraction (Figs 11A and 11B). Placing the straight wire with the canine mesially tipped favors distal movement of the crown, which results in diastema between the canine and the lateral incisor, thus favoring the resolution of crowding (Fig 11A).

Conversely, upright canines do not favor the opening of diastema, but it is probable that, in this case, the onset of retraction will happen more quickly (Fig 11B).

On the other hand, in case of distal tipping of canines (Fig 11C), alignment and leveling with straight wires may worsen the condition of crowding, in which case there is a tendency towards mesial movement of the crown. The use of elastomeric chain or springs for canine bracket in the posterior region is also contraindicated to

avoid mesialization of the crown, given that these devices favor distal tipping of the crown. Additionally, extrusive and undesired forces will be incorporated in the region of incisors during alignment.

Thus, it is recommended that segmented mechanics be used with reactive members and pre-activated T-loop springs, and that it be horizontally activated in accordance with the mesiodistal tipping of canines. For instance, in case of mesial tipping, the T-loop spring may be horizontally activated until canine up-righting is achieved. As for upright canines, a standard T-loop spring is used, i.e., with pre-activations (moment) and horizontal activation, producing translatory movements. In case of distal tipping, pre-activations (moment) may be initially used. After distal movement of canine roots is produced and up-righting is achieved, standard T-loop spring activation begins. Anti-rotation bends must be considered to overcome the tendency towards rotation of canines, also treated according to the position of canines in the dental arch. A complete description of T-loop spring biomechanics is found in publications by Martins et al.<sup>1,4,8,9,14-17</sup>

## DEEP BITE

Deep bite is a multifactorial vertical malocclusion that needs a differential diagnosis comprising facial, dental and cephalometric data as well as data on the vertical positioning of incisors at rest, smile and speech.<sup>18</sup>

It may be treated by extrusion of posterior teeth, intrusion of maxillary and/or mandibular incisors or a combination of procedures.<sup>18</sup>

Intrusion of incisors was considered for many years as a complex orthodontic movement. In fact, it is a technical movement that must be carefully planned. The use of straight wires hardly produce pure intrusion of incisors, instead, it leads to extrusion of posterior teeth. In other conditions, such as in appropriate anterior overbite, alignment and leveling achieved with straight wires may lead to deep bite, given that canines with severe root mesial tipping (Fig 11C) during correction cause anterior overbite to deepen. Following this line of reasoning, using archwires to level the curve of Spee (excessive in the maxillary arch and reverse in the mandibular arch), regardless of the type of alloy, will promote extrusion of posterior teeth, especially of premolars, followed by pseudo-intrusion of incisors (more buccal tipping than pure intrusion) (Fig 12).<sup>18</sup>

A systematic review conducted in 2005 concluded that the movement of intrusion is feasible and more easily achieved in the mandibular arch than in the maxillary arch. The study revealed that the segmented arch technique is most commonly employed for intrusion of incisors, with 1.5 mm of intrusion of maxillary incisors and 1.9 mm of mandibular incisors.<sup>19</sup>

Intrusion of anterior teeth can be basically achieved by means of two types of mechanics: straight wire appliance and three-piece arch appliance. The former consists of a segment of wire placed along the dental arch and, in the anterior region, placed on the teeth by directly fitting into the bracket slots (Ricketts arch) (Figs 13A, 13B and 13C) or by being tied to another anterior segment (Burstone arch) (Fig 13D).

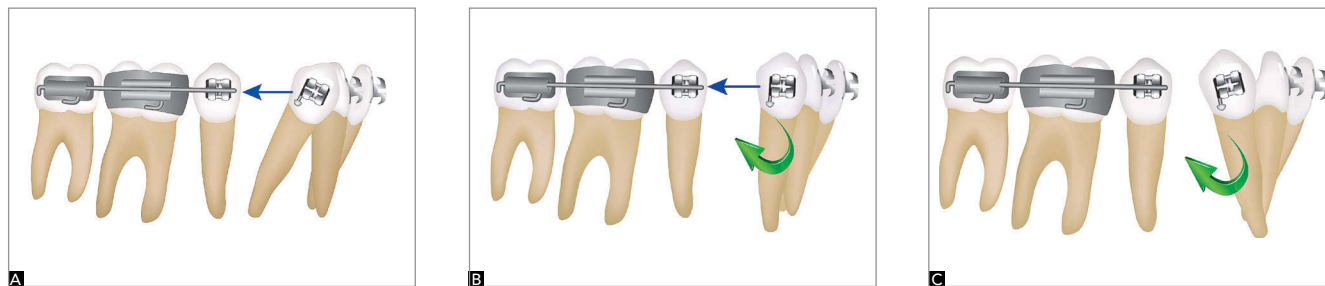


**Figure 11** - (A) Mesially tipped canine and the initial need for horizontal force, only. (B) Upright canine must undergo translation movement, i.e., a combination of horizontal force and moment. (C) Distal tipping of canine initially suggests the application of moment for root movement.

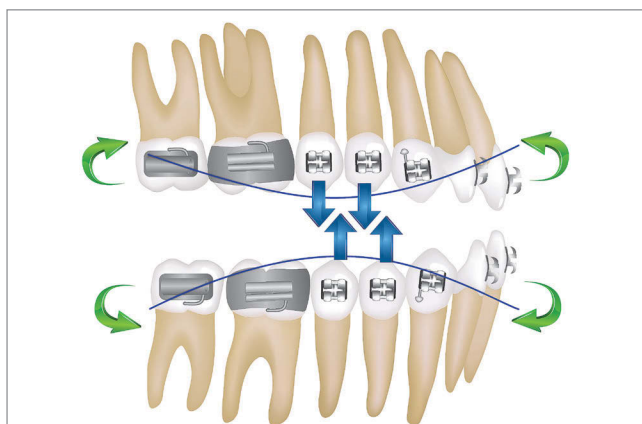


**Figure 12** - Summary of the mechanical effects of arches used to manipulate the curve of Spee.

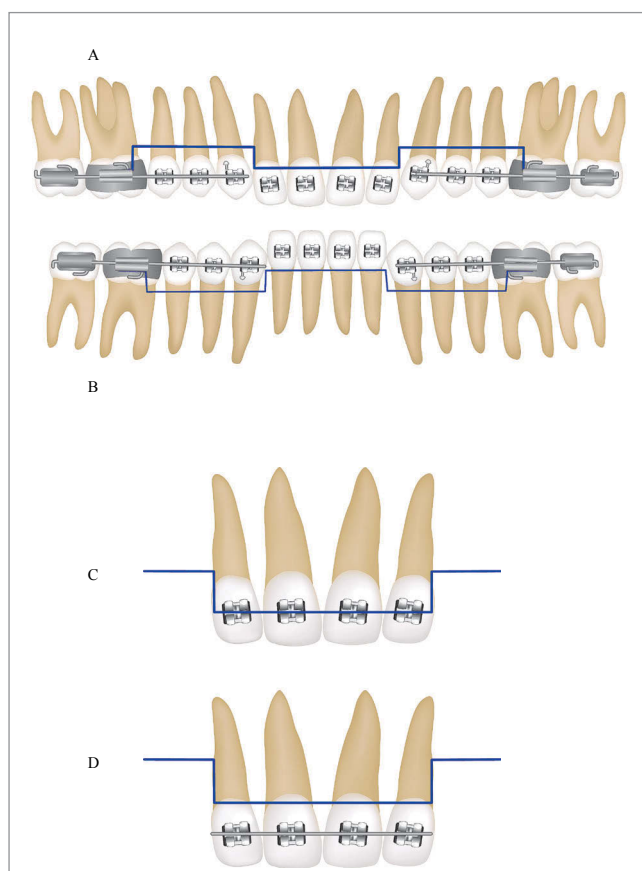


**Figure 13** - Illustration of the straight wire intrusion system. (A) maxillary intrusion arch; (B) mandibular arch; (C) bracket fitting; and (D) fitting in another segment of wire.

As for the three-piece arch appliance, two intrusion cantilevers are fabricated (one for each side) and inserted into another segment in the anterior region (Fig 14). Using a segment of wire in the anterior region, isolating

the area, is a much more predictable and understandable alternative. Should the intrusion arch be directly inserted into the anterior bracket slots (Fig 13C), undesired torques may be incorporated, and a more complex and undetermined mechanical system may be produced.

Regardless of the type of fitting, good anchorage control must be achieved due to the forces and, especially, the moments created by the system of intrusion (Fig 15). The largest number of posterior teeth must be incorporated into posterior segments, with lingual or palatal arches used to gather posterior segments into one single anchorage segment.<sup>2</sup> Additionally, the use of a high-pull headgear and short power arm angulated upwards is also recommended to balance the adverse effects of this mechanics. Likewise, the use of mini-implants or miniplates is also recommended.

According to Burstone, the key to success in intrusion is controlling the system of forces. Light, constant forces must be employed, with the point of application and direction of force carefully assessed. The magnitude of force must range from 10 to 15 gf per incisor. To calculate the total force, the teeth that will potentially undergo intrusion must be added up and the corresponding load must be applied. The magnitude of force is of paramount importance to yield satisfactory clinical results. For this reason, it is recommended that precision dynamometers be used to calculate the appropriate load.<sup>2</sup>

Researches have been conducted on the point of force application in order to provide appropriate intrusion of maxillary incisors. The results yielded by these studies led to clinical assertions that oftentimes result in errors. When all four incisors need to be intruded with maintenance of axial inclination (without moment production), intrusive force must be applied near the distal surface of lateral incisors. In order to produce intrusion and buccal tipping of incisors, force must be mesially applied to lateral incisors, whereas for intrusion with retroclination, load must be distally applied to canines.<sup>20</sup>

Santos-Pinto<sup>21</sup> also suggests other points of force application, which vary between pure intrusion and intrusion associated with buccal tipping or retroclination, according to the objectives of treatment (Fig 16).

It is worth mentioning that these points of force application must be adapted to the conditions of each clinical case. Depending on the degree of axial inclination of incisors, such points may be more anteriorly or posteriorly displaced.

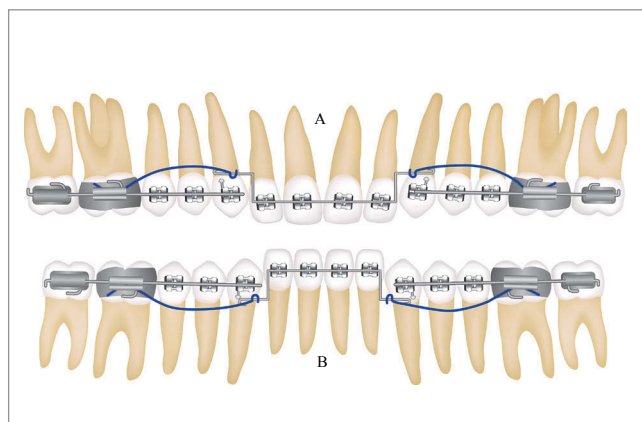


**Figure 14** - Illustration of the three-piece arch appliance intrusion system. (A) maxillary arch; (B) mandibular arch.

Some clinical conditions require not only intrusion of incisors, but also intrusion of canines, in which case it is recommended to begin deep bite correction by canines followed by incisors. Figure 17, for instance, shows the use of a three-piece arch appliance, with two segments posteriorly placed and one segment placed on the incisors without including the canines. Two cantilevers were fabricated with  $\beta$ -Ti wire for intrusion of canines on both sides. Subsequently, when canines are overcorrected or on the same occlusal plane of posterior teeth, they are incorporated to the poster anchorage unit, after which intrusion of incisors is performed.

Today, intrusion of maxillary incisors has been rarely used as the only resource to treat deep bite, given that exposure of maxillary teeth and a narrow section of gingival tissue yield more esthetic results, giving the patient a younger appearance.<sup>18</sup> Slightly extruded maxillary incisors are generally more esthetic than slightly intruded teeth.<sup>22</sup> On the other hand, in very specific cases, intrusion of maxillary incisors is well recommended.

In addition to the aforementioned procedures, intrusion and simultaneous retraction of maxillary incisors are highly recommended not only for antero-superior intrusion, but also for retraction, effectively controlling axial inclination of those teeth.<sup>23</sup> In these cases, in addition to the three-piece arch appliance, retraction appliances, such as elastomeric chain or springs, are also used, thus incorporating new forces and moments into the system (Fig 18). Similarly to the mechanics described in Fig 15, good anchorage control must be implemented so as to overcome the side effects of the mechanics.

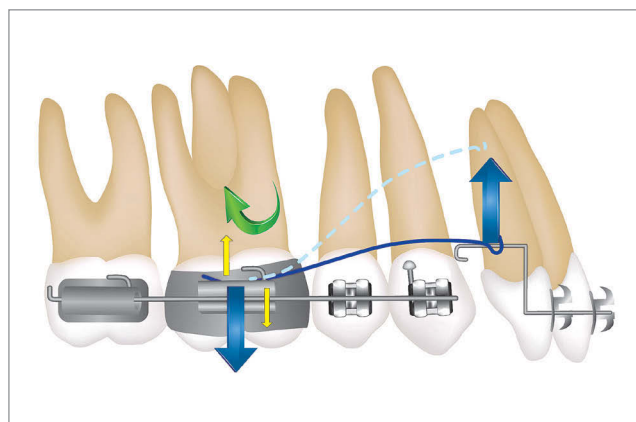


**Figure 15** - Intrusion system with the forces and moments produced.

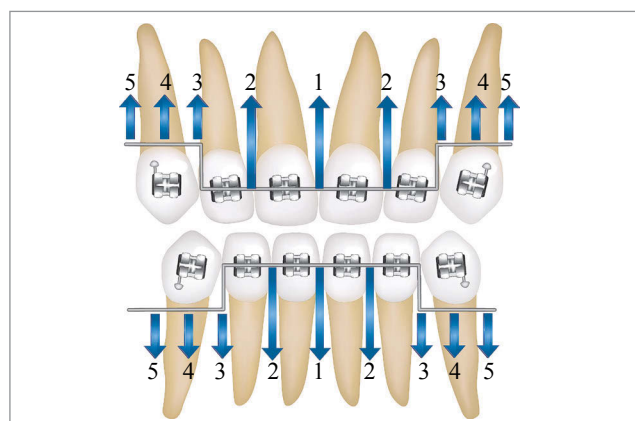


**Figure 16** - Different points of force application and mechanical effects on incisors: 1, 2 and 3 = intrusion + buccal inclination; 4 = intrusion; and 5 = intrusion + retroclination.

As it has been previously mentioned, in many clinical situations, alignment and leveling achieved by means of straight wires may cause deep bite. Furthermore, in case of extraction of first bicuspids, partial retraction of canines with straight wires also increases deep bite. Figure 19 shows how deep bite was achieved after alignment, leveling and partial retraction of maxillary canines. In these cases, retraction of incisors becomes a difficult task to be achieved due to the lack of overbite and overjet necessary for retraction. In this example (Fig 19C), the arch of intrusion and simultaneous retraction was used for retraction of incisors with greater control of axial inclination without necessarily promoting real tipping. At treatment completion (Fig 19D), we observed that retraction was achieved

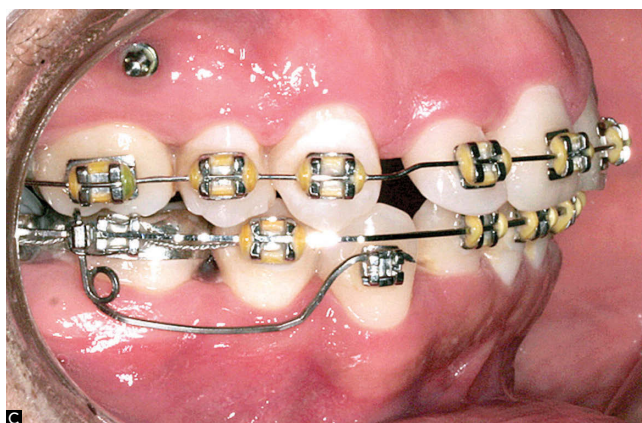
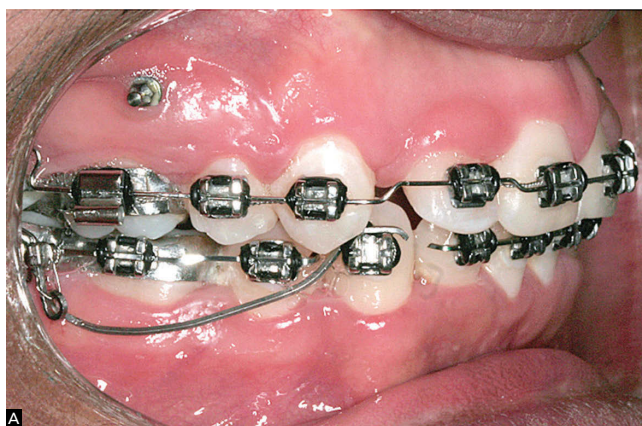


Figure 17 - Clinical illustration of a cantilever used for canine intrusion.

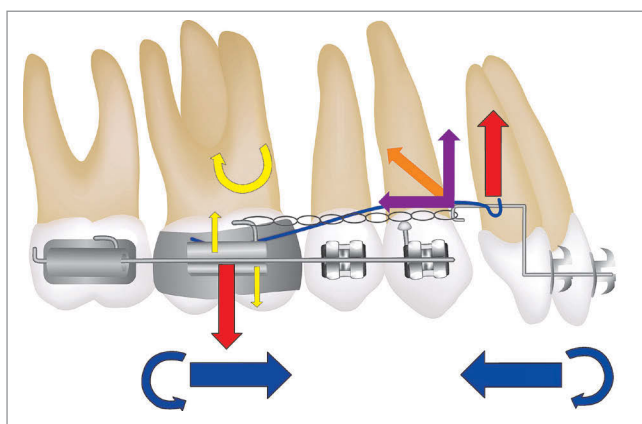


Figure 18 - Mechanical illustration of forces and moments in the segmented arch technique employed for simultaneous retraction and intrusion of incisors.

with correct inclination of incisors, whereas anterior overbite remained unchanged, preventing potential deleterious impact on the degree of teeth exposure at smile, rest and speech.

## MOLAR UPRIGHTING

Molar uprighting is widely employed in cases of early loss of deciduous teeth followed by deleterious dental migration in young patients and in orthodontic treatment of adult patients with tooth loss. In these cases, molar uprighting is generally associated with extrusion of antagonist teeth, reduction in edentulous space, bone dehiscence in the mesial surface of tipped molars, gingival recession of tipped molars, early contact in centric relation and occlusal interference on excursion of the mandible.<sup>24</sup> With regard to integrated planning, clinicians must decide whether the tooth subject to uprighting will undergo movement for space closure, opening of space for prosthetic rehabilitation or implant placement.

Mesial movement of molars may be rendered difficult due to the following: alveolar bone resorption resulting from tooth loss, which causes the molar mesial bone to become too thin; unfavorable root morphology for movement of lower molars; greater

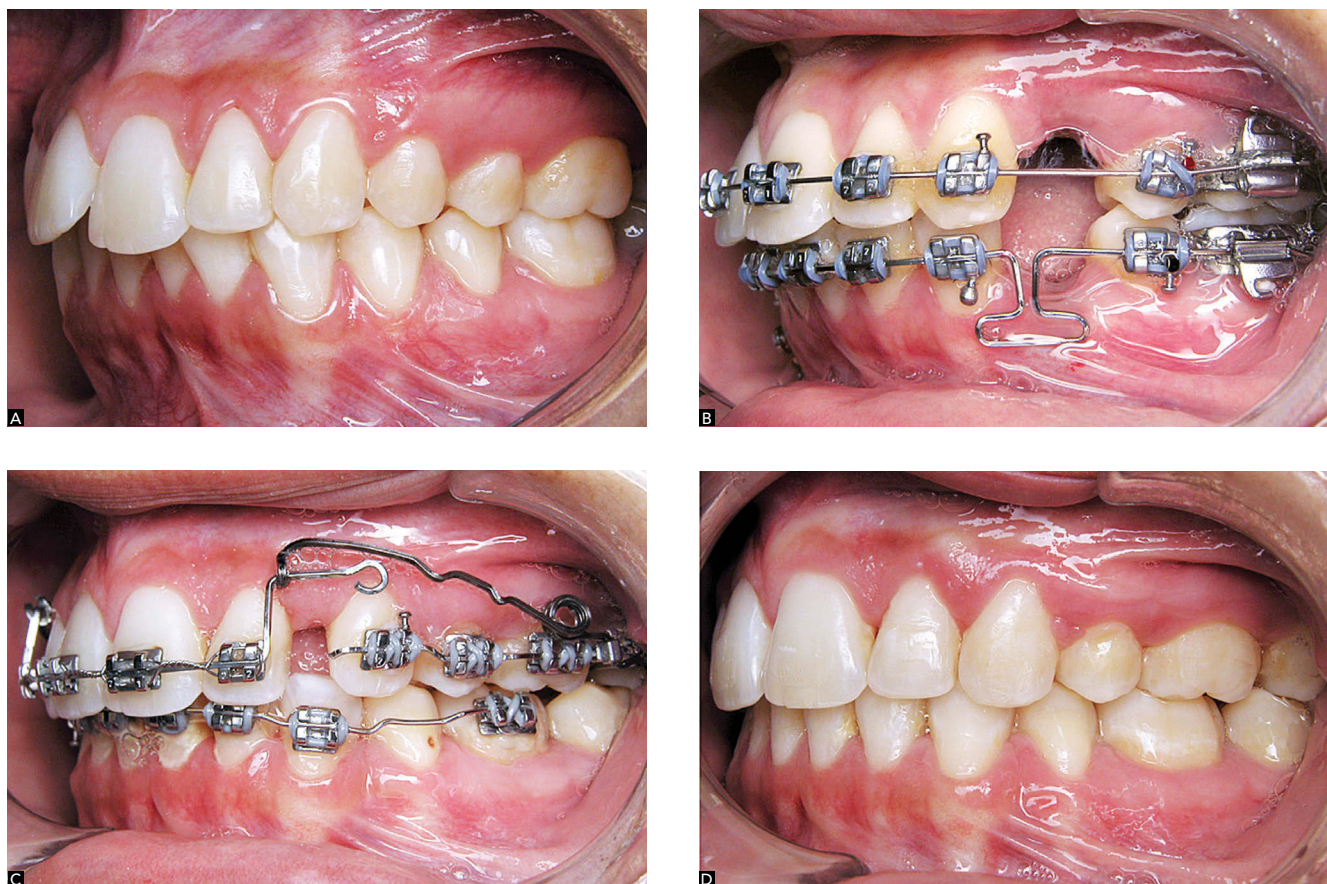


**Figure 19** - Clinical illustration of SAT used for simultaneous retraction and intrusion of incisors: (A) initial case; (B) during maxillary alignment and leveling; (C) deep bite after alignment and leveling completion, and partial retraction of canines; (D) final result after placement carried out by means of the segmented arch technique.

mandibular bone density in relation to the maxilla; and thin buccolingual bone thickness from distal to mesial in the mandibular arch.

Using straight wires to upright tipped molars is considered unfeasible, given that, in these cases, there is a strong tendency towards extrusion of molars, especially due to the short distance between brackets. Additionally, incorporating a T-loop spring into the arch will lead to extrusion of premolars.<sup>24</sup> A cantilever, extended up to the anterior region, may be used to reduce the effects of extrusion on molars. Researches have proved a moment of 1200 gf.mm to be appropriate for molar uprighting.<sup>25,26</sup> Should a 30-mm cantilever be used, an activation of 40 gf is enough for molar uprighting (Fig 20), in which case 40 gf corresponds to intrusive forces in the anterior region and extrusive forces in the region of molar teeth. Mesocephalic or brachycephalic patients are able to eliminate or reduce this effect of extrusion by their own muscular pattern; however, additional

studies are warranted to further investigate this topic. Another aspect that should be highlighted is whether or not the tooth subject to uprighting allows attrition, such as extensive restoration, on its occlusal surface. In other words, whether it is a tooth that will become a metal-ceramic crown that allows extrusion as it will undergo attrition.

Figure 21 shows a clinical case of side effects on occlusion resulting from loss of first molar and lower second premolar. The second molar was not included in the straight archwire during alignment and leveling. Subsequently, a  $\beta$ -Ti cantilever was used for two purposes: 1) molar uprighting and space opening for implant rehabilitation; and 2) correction of the occlusal plane in the anterior segment as a result of installing the cantilever in the midline, thus producing intrusive forces in this area (Figs 21B, 21C). With the molar near the occlusal plane, straight wires were used to go on with treatment and reach completion (Figs 21D, 21E, 21F).

In cases in which molar extrusion is impossible, springs or cantilevers supported by mini-implants can be used with the vector line of force passing under the molar CRes, so as to produce a resultant force that intrudes the molar. Another option to eliminate extrusion force is to use a double cantilever,<sup>27</sup> in which case one cantilever is used as in conventional molar up-righting, while the other is activated to produce intrusive forces on the molar. Thus, the effect of extrusion produced by the conventional cantilever is neutralized by the second cantilever. One disadvantage of this option is patient's discomfort caused by the concurrent use of two devices (Figs 22, 23).

### OCCLUSAL PLANE CORRECTION

Occlusal plane inclination is a daunting challenge faced by orthodontic treatment. It is mainly caused by dental issues such as loss and/or ankylosis of antagonist teeth, deleterious oral habits, inappropriate orthodontic bonding leading to asymmetric dental alignment, skeletal disharmony or a combination of factors.<sup>28</sup>

Most cases of skeletal facial asymmetry present significant changes in maxillary and/or mandibular occlusal plane. TJD-related pathologies (rheumatoid arthritis, condylar hyperplasia, osteochondroma, condylar resorption, and others) and craniofacial syndromes/deformities are the most common primary etiological factors of facial asymmetry that impairs the occlusal plane. In fact, abnormal mandibular impairment is initially observed in growing and non-growing patients.

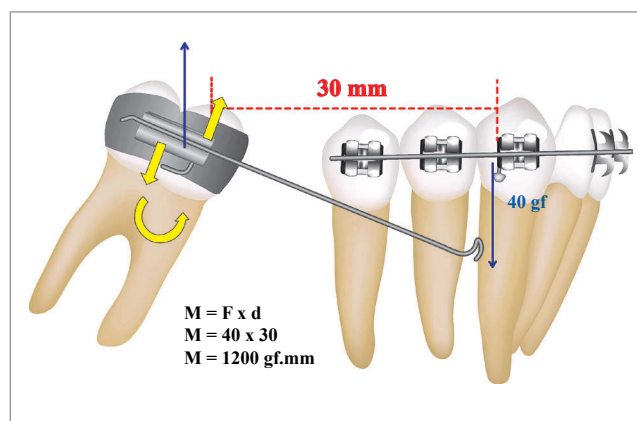


Figure 20 - Illustration showing the moment produced by the cantilever used for molar up-righting.

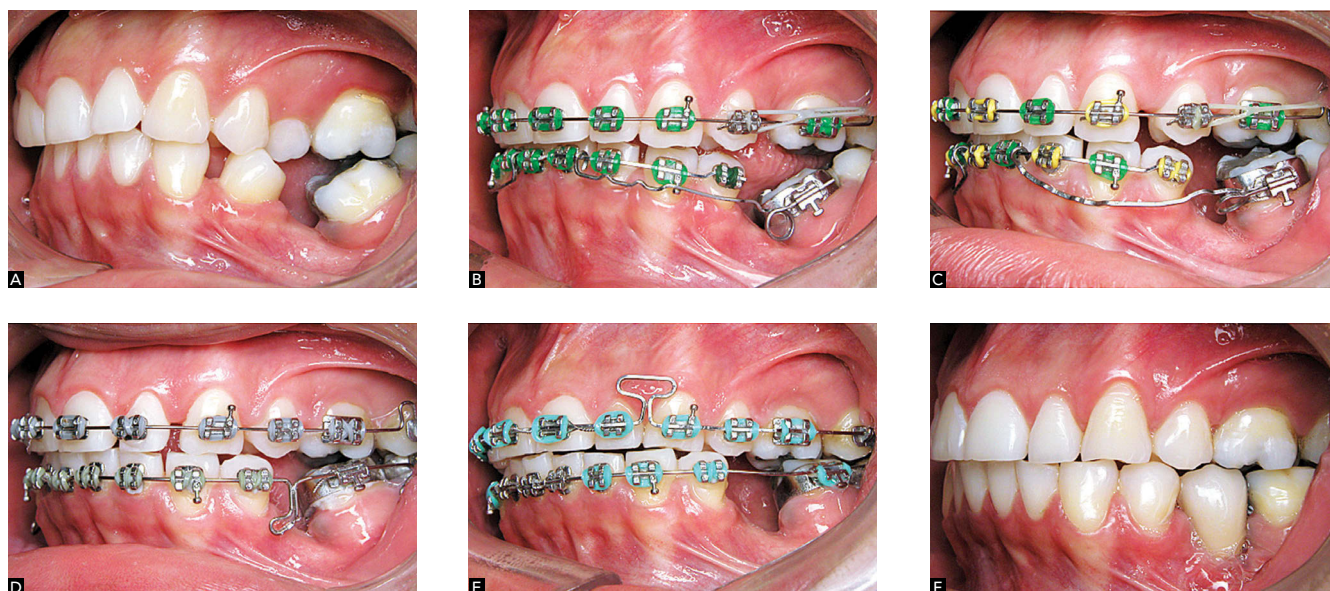


Figure 21 - Clinical illustration of a cantilever used for up-righting tooth #37.

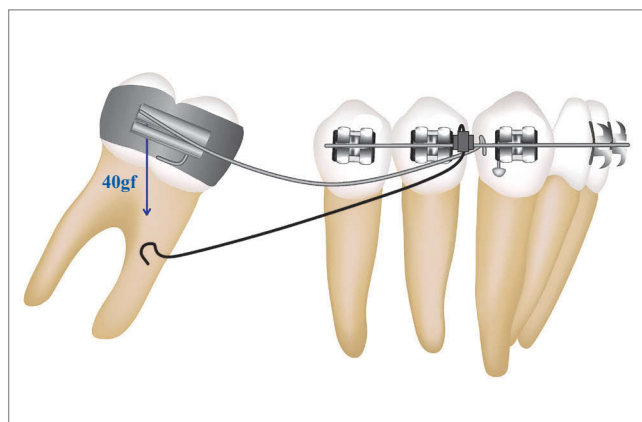


**Figure 22** - Illustration showing the effects of intrusion caused by activation of a second cantilever inserted into the cross tube, neutralizing the extrusive effects produced by the first cantilever.

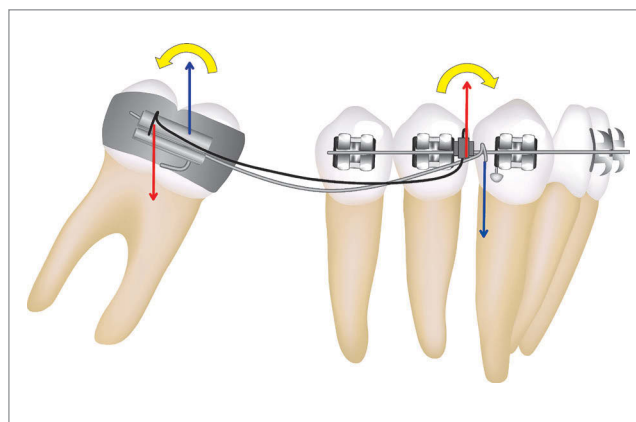


**Figure 23** - Illustration showing the neutralization of vertical effects on molar subject to uprighting.

However, to compensate such changes, the maxillary occlusal plane is also impaired so as to establish a balance between the mandibular changes.<sup>28,29</sup>

Treatment of those pathologies depends on the cause and degree of severity of the change. In cases of significant facial alterations, dental correction may be achieved by mini-implants or miniplates; however, no improvements in facial esthetics will be observed. Thus, an approach combining orthognathic surgery and orthodontic treatment is recommended. Nevertheless, in borderline cases in which patient's chief complaint is not facial, orthodontic approach alone is employed with considerable forceability.<sup>29</sup>

Mini-implants became popular and allowed those issues to be addressed in a more predictable manner, yielding excellent results.<sup>30</sup> Nevertheless, other biomechanical procedures that do not require skeletal anchorage can be employed to treat occlusal plane inclination. The rational use of biomechanics by means of SAT and asymmetric cantilevers proves to be a feasible option. As shown in Figure 24A, the patient, whose chief complaint was having an asymmetric smile, presents occlusal plane inclination. Due to the absence of facial complaints, she was advised to undergo dental treatment, only, which would be performed with asymmetric cantilevers.

Initially, alignment and leveling were carried out in association with anchorage preparation of the reactive member by means of a palatal bar.

The 0.019 x 0.025-in wire was achieved and the arch was segmented into three pieces (from #16 to #14, from #13 to #21 and from #22 to #25). Initial alignment and leveling did not include tooth #27 which was coupled with #16 by a palatal bar.

The segment going from #13 to #21 underwent a clockwise movement, with the point of force application between #13 and #12, where greater intrusion was observed. A 70-gf force was applied by a cantilever made of 0.017 x 0.025-in  $\beta$ -Ti wire (Fig 24B).

The segment going from #22 to #25 underwent an anti-clockwise movement, with the point of force application between #22 and #23. Extrusive force was applied by a cantilever made of 0.017 x 0.025-in steel wire. In order to achieve flexibility and decrease the LF ratio, a helix was placed in the wire with a force of (Figs 24D, 24E, 24F).

The side effects produced by the mechanics were balanced by the palatal bar reinforced with the use of a steel stabilization 0.019 x 0.025-in archwire placed from #16 to 14 on the right side. Treatment lasted for three months, followed by rebonding of brackets and new procedures of alignment and leveling (Figs 24G, 24H, 24I).



**Figure 24** - Clinical illustration showing the use of two asymmetric cantilevers. A, B, C) Initial case; D, E, F) Intrusion on the right side and extrusion on the left side for correction of the occlusion plane; G, H, I) After mechanics was applied.

## FINAL CONSIDERATIONS

Today, orthodontists must keep distance from conceptual dogma and be open to new information that contributes to perform orthodontic treatment as effectively as possible. Knowing how to deal with potential side effects is essential for orthodontic therapy, given that such effects may hinder treatment and, in many cases, cause loss of control.

In addition to the aforementioned situations, the segmented mechanics may be employed in many other branches of Orthodontics, namely: anterior retraction, use of palatal bar and removable lingual arch (correction of rotation, distalization, arch expansion or contraction),

extrusion of incisors, etc. Therefore, understanding the principles behind scientific biomechanics is crucial to yield great clinical results with as little side effects as possible. In this context, SAT proves to be essential as an auxiliary resource that aids the straight wire technique in several clinical situations.

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Consequentemente, recomendamos aos autores que procedam o registro dos ensaios clínicos antes do início de sua execução.

Atenciosamente,

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