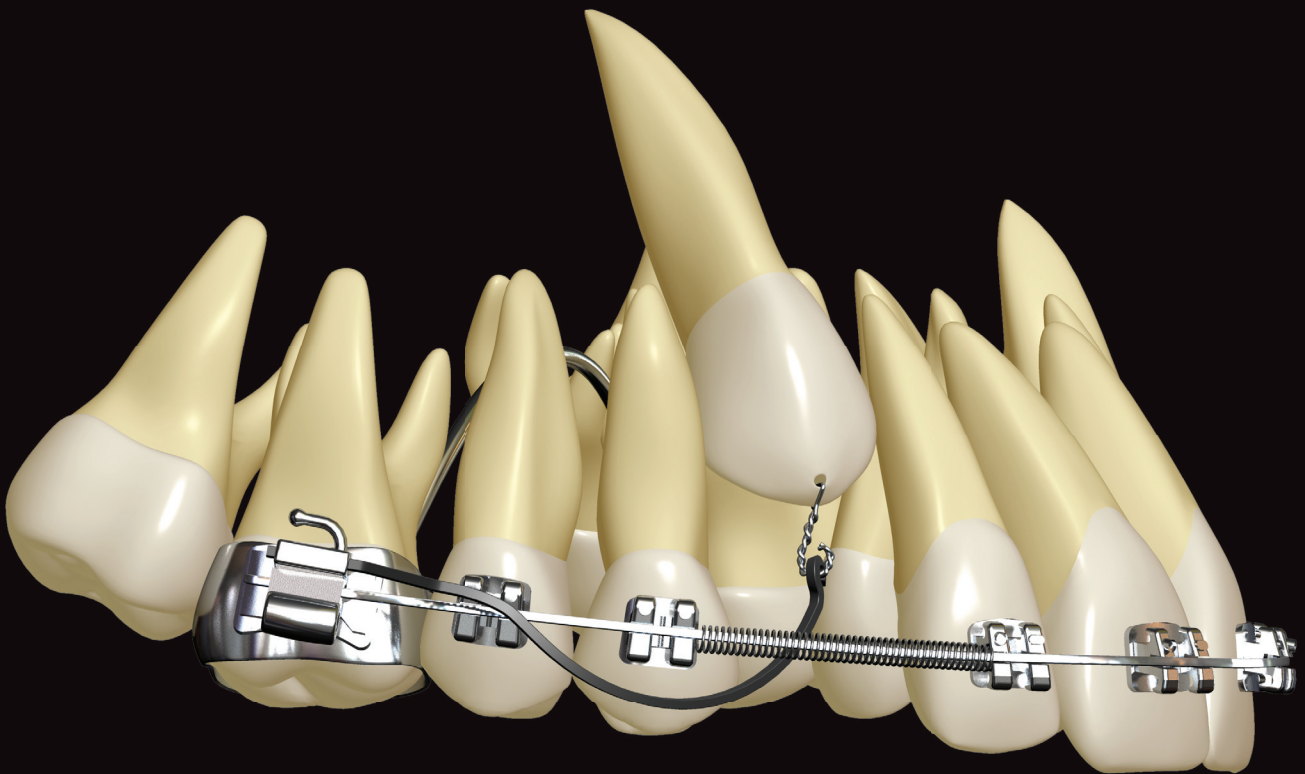


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Articles, websites or books. Where to find the information we need?

Where should we seek information if we need to make a treatment decision? In an article, website or book? Curiously, this is not as straight forward as it may seem for most professionals, and be even more confusing for laypersons. Let us roll up our sleeves and address the issue.

Scientific articles are the most precious source of information available today. They provide the most current, up-to-date information and if we take a close look at a study design we can easily understand the place occupied by that particular study in the pyramid of evidence. In other words, equipped with some knowledge of evidence-based dentistry a reader can assess exactly to what extent a given article is relevant to clinical practice. Furthermore, articles have to prove their mettle by meeting stringent requirements before publication in a journal. Thus, information is filtered and polished prior to being delivered to the reader. A shortcoming of scientific articles lies in the fact that they target professionals, not laypersons.

Websites offer the advantage of making information accessible to laypersons. However, websites are probably the most controversial sources of knowledge. They are a mixed bag, ranging from great to lousy. They gave rise to the most famous and widely consulted doctor today: Dr. Google. This doctor arouses radically contradictory feelings. At times we are truly happy to see Dr. Google help someone to avert an inadequate treatment. On other

occasions, it provides patients with dreadful content, and we are hard put to spend a huge amount of time and saliva to explain why it is wrong. We can never warn enough that Dr. Google is not a fully reliable source of information, and professionals are advised to resort to it with caution.

The problem of information on the Internet is that websites will accept any and all information. As a result, a whole lot of ignorance is being spread on the Internet. However, there are also fantastic initiatives committed to clarification and knowledge, such as the Cochrane Collaboration,¹ a space where readers can find the most authoritative content on various health care themes. The Cochrane Collaboration has been cited as an enterprise that rivals the Human Genome Project in its potential implications for modern health treatments. This is a source for laypersons and professionals alike.

It is curious that although books have been our companions for centuries, they are still largely misunderstood by people in general. An old adage says that in order for a person to feel fully accomplished they need to plant a tree, write a book and beget offspring. Nevertheless, it takes a little browsing in a bookstore to see hundreds, perhaps thousands, of low quality books. How do we sort the wheat from the chaff in health care? It's elementary. We must understand the role books play in our particular area.

Books will passively accept information of any quality on their pages. In fact, good books comprise an author's approach to a given subject or subjects, usually based on topics they had previously addressed in scientific articles. That is, the author has published several articles. This information was tested by the scientific community and from a certain moment onward the author will consistently organize such body of information and put it into context for the readers. Often, outsiders' eyes will fail to see in these articles the alignment and consistency that is so obvious to the author, and which they expound in their book. Thus, this type of source provides a unique overview of the work carried out by someone or a group.

It is precisely due to their readability and consistency that books are often used by undergraduate students. The goal is to render

information that is more user-friendly and intuitive, and thus ideal when taking the first steps in professional training.

One great example is the book *Controversies in Orthodontics and Atlas of Tooth Movement Biology*, by Alberto Consolaro.² In his book the author rounds up the information initially presented in the form of articles, which were sieved by the dental community, thereby providing an overview of the author's amazing stances on a wide range of issues tackled in day-to-day clinical practice.

Thus, there are all sorts of scientific articles, websites and books. Make sure to choose your source wisely.

Good reading.

Jorge Faber
Editor-in-chief

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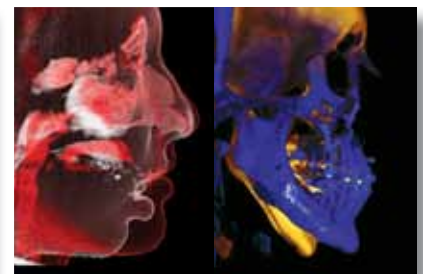
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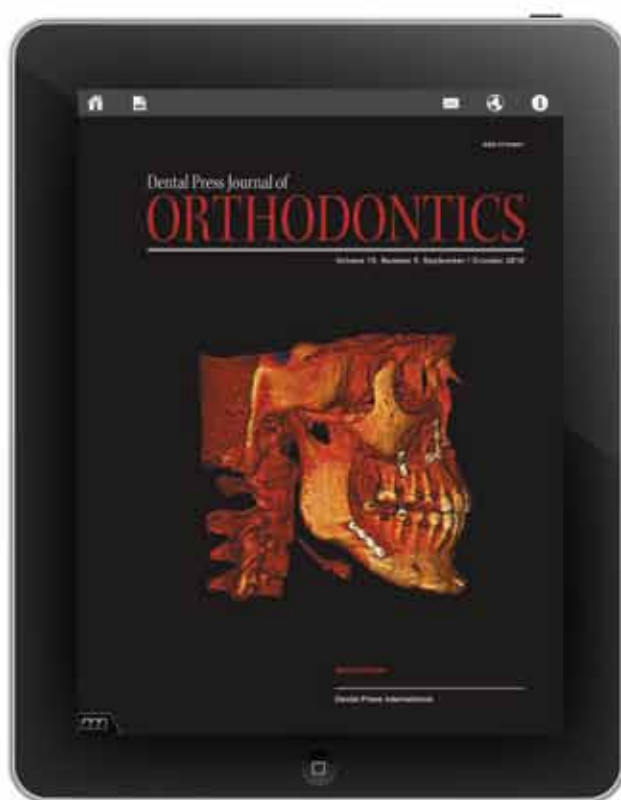
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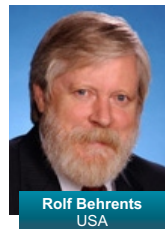
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Expanding therapeutic boundaries: Stem cells and tissue engineering

Roberto Rocha*

Over the last decade, research in dentistry has been evolving expressively in the field of tissue engineering. The search for means to achieve tissue repair, or the generation of new tissue, has the goal to broaden dramatically the therapeutic possibilities over different areas. Tissue engineering is a very promising option for providing tissue for craniofacial repair.⁵ When added up, the incidence of incisor pre-foramen fissures, which involve the alveolar ridge, and of incisor transforamen fissures, the presence of a full or partial alveolar cleft affects something like 70% of the cleft lip and palate patients.

From an orthodontic therapy point of view, the presence of an alveolar cleft represents the greater management challenge for limiting dental movement in the area adjacent to the cleft. It is paramount to be aware to the constraints imposed by this condition to patients rehabilitation.^{1,2,11,12} Aimed at facing this difficulty, the use of secondary alveolar bone graft has been considered the first choice of treatment. Although its efficacy has been largely registered by both literature and clinical practice, this procedure involves complex issues such as cost, general anesthesia, the need for an orthopedic practitioner when the donor site is the iliac crest, morbidity, amongst others. New discoveries have been pointing out towards the development of less invasive and equally efficacious strategies. The American Association of Orthopaedic Surgeons suggests that, given the high demand for grafting procedures, the

development and supply of “substitutes for conventional bone grafts” should be a priority. In a recent study,⁵ embryonic stem cells have been differentiated into cartilage cells and implanted on artificially created cranial osseous defects. In comparison to the control group, the group that received the implanted tissue had a significantly faster response rate.

Stem cells biology has become an important field of knowledge as a means to understand the tissue regeneration process. It is essential for bioengineering to have a triad comprised of: stem or progenitor cells; a matrix that will serve as a framework for the cells; and signalling proteins, called growth factors, as a booster for cell differentiation.¹⁰ By and large, stem cells present two major features: They have self-renewal capacity and, when multiplying, they may still remain with the features of a stem cell or may differentiate into a wide range of other cell types.^{6,7} Dental pulp is actually among the richest tissues in mesenchymal stem cells, which bear a huge application potential for tissue engineering purposes. That happens thanks to the fact that this type of dental tissue is multi-potent and has a high proliferation rate, what makes dental pulp a very valuable source of mesenchymal stem cells to be destined for tissue repair.³

In another work, the feasibility of dental pulp from deciduous teeth as an eventual source of stem cells for pulpal tissue engineering has been studied.⁴ Mesenchymal stem cells taken

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from the pulp of permanent teeth have already made it possible to develop pulpal tissue, with roughly normal features, over a previously prepared framework.⁸ Currently, there is a greater tendency towards using adult stem cells rather than embryonic ones. Some of the reasons that justify this trend are: Adult stem cells involve less complex ethical issues and offer greater control over cell proliferation and differentiation aspects. Embryonic stem cells tend to present disordered and uncontrolled growth, presenting a tumour-like aspect sometimes. This fact may be related to the synergic context and the functional memory of those cells. Cells from embryonic origin are aligned with a development phase when growth and differentiation rates are fairly high if compared to adult stem cells.

Presently, individually created tissues seem to be a more tangible promise within a reasonable time frame.⁷ Teeth that underwent external root resorption for orthodontic reasons, for instance, are not likely to recover the tissue loss. That would seem to positively change research evolvement. The apical papilla differs from the dental pulp for containing less cellular and vascular components.⁹ However, apical papilla stem cells have shown to have both high repair and differentiation potential. Proof of that may be found in some situations when traumatized and incomplete root formation permanent teeth underwent pulpectomy and subsequent endodontic therapy, and were still able to keep on with the apexification process. These findings open the possibility of using stem cells from apical papilla (SCAP) as well as other types of

stem cells for pulp and dentin repair, together with the association between SCAP and periodontal ligament stem cells. This possibility has been called the BIOROOT ENGINEERING.⁶

Tissue development involves the synergy between events and substances in a rather broad and complex spectrum. The ultimate understanding of agents, its functions and the synergic context leads to quite a long way ahead. Nevertheless, results are quite promising and as research methods get enhanced, evolution is just around the corner. A great hurdle still remains in accomplishing the development of periodontal ligament fibers adequately arranged in the interfaces between cement and alveolar bone. Knowledge already provides us a good enough understanding of how to program and stimulate differentiation. However, controlling the location and the amount of growth still remains as a huge obstacle to be overcome. Looking back 15 years, when stem cells research started, and coming to present times, knowledge has been expanding exponentially in this field. But for every new discovery, new ethical dilemmas, questions and challenges also unveil themselves. There is an urgent need for courses of graduation to update their curriculums towards cell biology education, under the light of the current knowledge, as well as for molecular biology. Contemporary orthodontic practitioners should review and deepen their knowledge in those fields. This stands out as a foremost condition to be able to absorb new technologies emerging from bioengineering and extend to patients its significant close coming benefits.

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Intrusive mechanics generates inclination forces and orthopedic stimulus followed by simultaneous dental repositioning and bone remodelling

or

Intrusion forces are not applied in intrusive mechanics, but intrusive effects are still obtained

Alberto Consolaro*, Laurindo Furquim**

Abstract

The low intensity and long duration aggressions to the periosteum induce the formation of new layers and can increase the volume of bone and change its shape. In intrusive mechanics, the natural inclination of the roots provides the tooth inclination movement. At the same time that it promotes compression forces on the periodontal ligament of teeth subjected to this kind of mechanics, in other areas, tension forces with deflection occur. These effects also involve the outer surfaces, since the thickness of the bone in the alveolar process is thin and can lead to the formation of new layers, including the cervical part of the alveolar bone crest. In intrusive mechanics, there is an alveolar remodeling with orthodontic nature associated to a modification of bone internal and external structure, satisfying the demand for forces with orthopedic features. The intrusive effect on the so called intrusive mechanics may be the result of alveolar remodeling induced by the inclination forces, and of the modification of bone volume due to subperiosteal bone formation on the outer part of the alveolar process. Probably accurate imaging studies, with high precision CT, will be able to detect these subperiosteal phenomena in future studies involving patients before and after application of intrusive mechanics.

Keywords: Intrusion. Orthodontics. Orthopedics. Periosteum.

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Intrusion is frequently pointed out as one of the great risk causes for resorption on the root apex and at interradicular furcal regions.² This risk would be greater if compared to other tooth movements. Despite the suggestion that apical root resorption depends on the intensity of orthodontic movements,¹⁰ many works reveal that there is no relation between dental resorption and intrusion.^{3,5,6,7,11,12} Carrillo et al,² in 2007, used specific appliances with full anchorage by means of plates and osseointegrated implants in dogs teeth and were not able to verify root resorption through imaging. Although some intrusion effects did take place, resorptions observed were considered insignificant.

Experimental results obtained by Carrillo et al² were similar to those obtained by other authors,^{4,9,5} even when teeth were microscopically observed after 4 to 7 month of intrusion. Microscopically, root resorptions were small and in the apical and furcal areas of molar teeth of dogs and did not offer images reliable enough for a precise diagnosis. Clinical surveys with important intrusive effects also revealed that the tooth resorption index was either very low or inexistent^{1,8}.

Pure intrusive orthodontic forces are solely applied for experimental purposes and in these papers evidences reveal that whenever apical or furcal resorption take place on these teeth, they can only be observed microscopically, going undiagnosed after imaging exams.^{2,4,5,9} Results of these works also suggest that when intrusive forces are eliminated, surrounding tissues would promptly promote healing to the resorbed areas.

In the present work, we have attempted to give the biological basis as to why purely intrusive forces are not generated in orthodontic therapies, even under the so known intrusive mechanics, through which clinically relevant intrusive effects are obtained. In order to understand the conceptual fundamentals of intrusive mechanics it is paramount to review the concepts of osseous biology,

concerning origin, structure and function of dental and skeletal components involved in this important option for orthodontic treatment planning.

BONE AND BONE TISSUE: THEY ARE NOT THE SAME THING!

Bones represent anatomical structures comprised of different tissues that interact to play specific roles, namely:

- a) Bone tissue, a specialized connective tissue, in which an organic matrix is deposited and mineralized, forming two typical structures: Cortical bone and trabecular bone. In the mineralized bone matrix there are numerous cells, osteocytes (Figs 1, 2 and 3) embedded in gaps called osteoplasts.
- b) Bone marrow, a hematopoietic tissue that produces blood cells and platelets. It may last until the end of one's life or cease to function on an earlier stage. Adult's jaws only persist as hematopoietically active in the maxillary tuber, mandibular angle and condyle; in macroscopic sections it presents a red colour. As it becomes atrophic, the red bone marrow is gradually replaced by adipose tissue and/or fibrous connective tissue and presents a yellowish colour. Bone marrow, especially the hematopoietically active, is very rich in undifferentiated cells or stem cells, containing also the primitive cells that generate many leucocytes, red blood cells and platelets.
- c) Fibrous connective tissue represented by the periosteum (Figs 1 and 3), a truly structural and functional interface between bone and peripheral soft tissues, specifically muscles and tendons. The endosteum, rich in osteoblasts and reserve progenitor cells or tissue stem cells, is considered a thin connective tissue membrane almost inseparable from the osteoid — a delicate layer of non-mineralized bone matrix over trabeculated surfaces — and continues

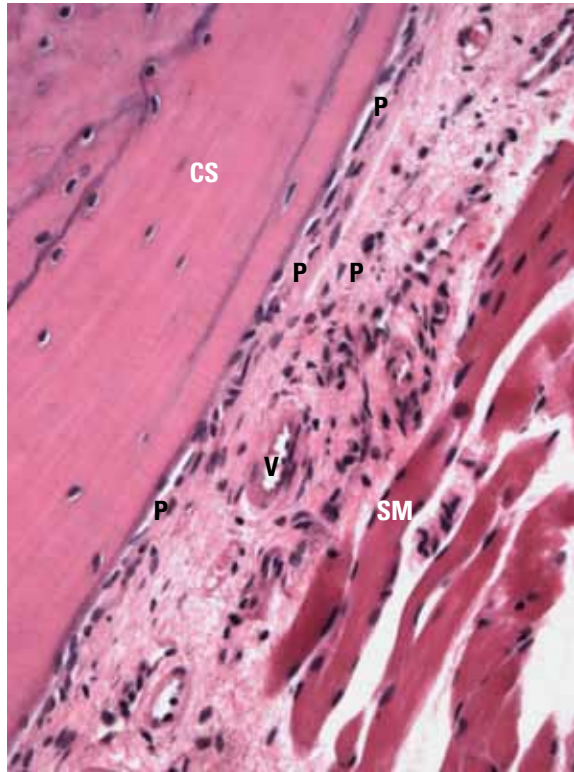


FIGURE 1 - On the bone cortical surface (CS) periosteum reveals numerous bone cells in nature, particularly osteoblast and reserve cells with great osteogenic potential. Periosteum (P) still distributes blood vessels (V) and presents extra-cellular matrix externally, including collagen fibers that interact structural and functionally with skeletal muscles (SM) and tendons, besides other soft tissues. (H.E.; 20X).



FIGURE 2 - When stimulated by long duration low intensity stimulus such as long duration light forces, associated or not to bone deformation, periosteum (P) reacts apposing bone over the interface in a lamellar pattern and parallel to the cortical (C), a condition known as ossifying periostitis (OP, between dashed lines). More towards the periphery, skeletal muscle fibers are associated to the outermost portion of the periosteum (SM). (H.E.; 20X).

externally as hematopoietic medullary tissue, adipose or fibrous tissue.

PERIOSTEUM CONCEPT AND FUNCTIONS

Bone surfaces are lined, covered and protected by the periosteum (Figs 1 and 3). Externally, this connective tissue membrane is very fibrous, capable of offering considerable resistance to debridement during surgical procedures, which requires special tools. Periosteum is firmly attached to the bone through attachment collagenous fibers that cross over its richly vascularized inner interface also rich in young and matrix producing cells. Blood supply mandatorily comes through the periosteum in order to get

to other bone structures (Fig 1).

The periosteum has many functions of which the soft tissue attachment stands out, particularly muscles and tendons. It is through contractions and force transmission to bones that the body movements. In muscle attachment areas, bone structures are thicker and present denser trabeculae in order to meet the greater functional mechanical demand.

Collagenous fibers of the periosteal connective tissue unite to muscles in continuity to the epimysium (Figs 1 and 3), a connective membrane that lines or embraces muscle skeletal fibers. Epimysium, on its turn, is attached to the sarcolemma or muscle fibers cytoplasmatic

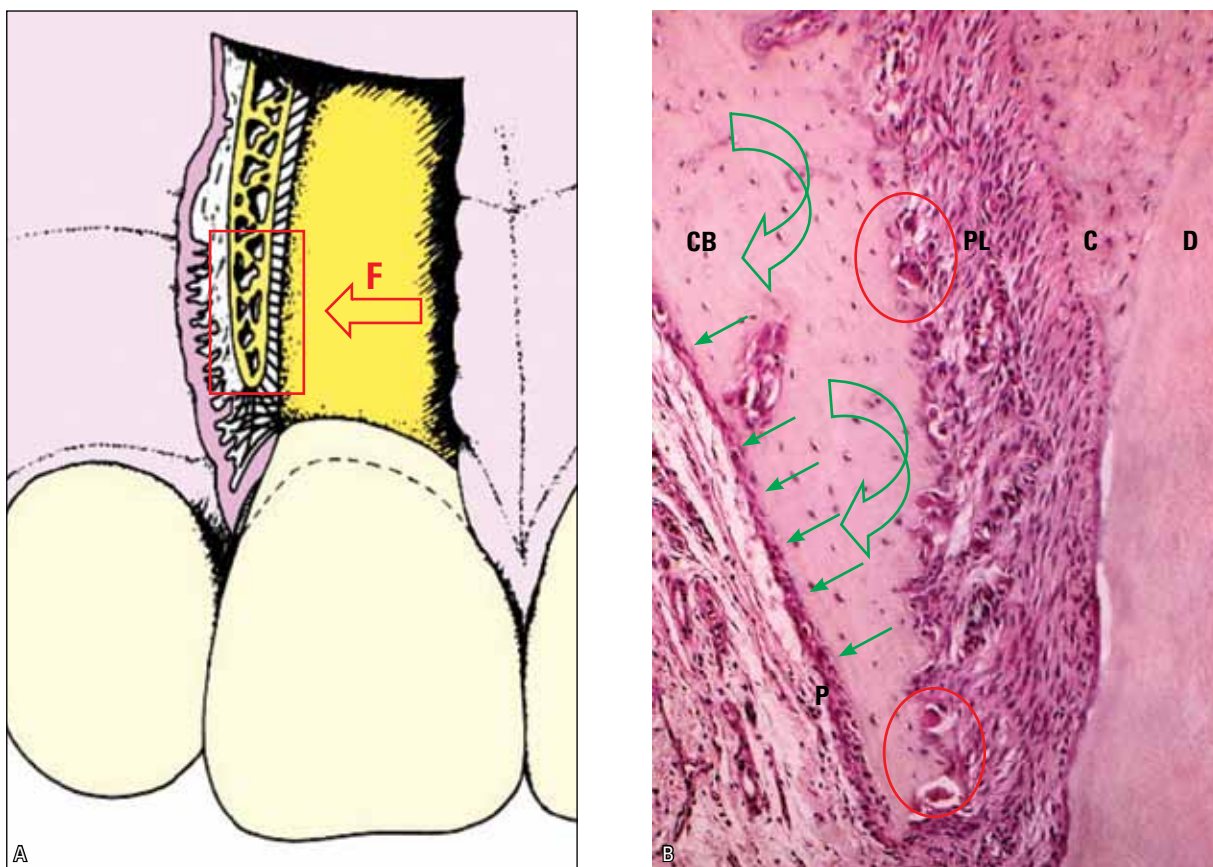


FIGURE 3 - During orthodontic movements, forces (F) may promote deflection (curved arrows) of the alveolar process and stimulate sub-periosteal new bone formation (arrows) along the interface between periosteum (P) and cortical bone (CB), while along the periodontal surface there is a frontal bone resorption characterized by bone remodeling (BMUs) units and its clasts (circles). C=cementum; D=dentin PL= periodontal ligament. (H.E.; 20X).

membrane through an extracellular matrix or membrane proteins.

When muscle contractions take place, muscle forces are transmitted to bones by the connective tissue junction between periosteum and epimysium. In some cases, forces are so intense and concentrated that they demand a stronger connective tissue, specifically organized for this purpose in the form of tendons. Tendons represent fiber stripes or cords through which muscles attach to bone or other organs. They are paramount to the maintenance of static and dynamic balance of the body through the transmission of muscle forces to bones and joints. The whole set of concerted forces from the dif-

ferent muscle groups produces flexion, extension, rotation, abduction, adduction and translation movements.

The periosteum's reactional capacity in face of eventual injuries or long lasting low intensity stimulus promotes the apposition of new bone layers over the demanded area, arranged as an onion peel over the cortical interface (Figs 2 to 5). This may occur in deflections and deformations thanks to the limited bone elasticity in the presence of stress, pressure, discrete or prolonged inflammation processes, subperiosteal contusions, as well as surgical procedures or any other type of long lasting low intensity stimulus. During the dental movements induced on

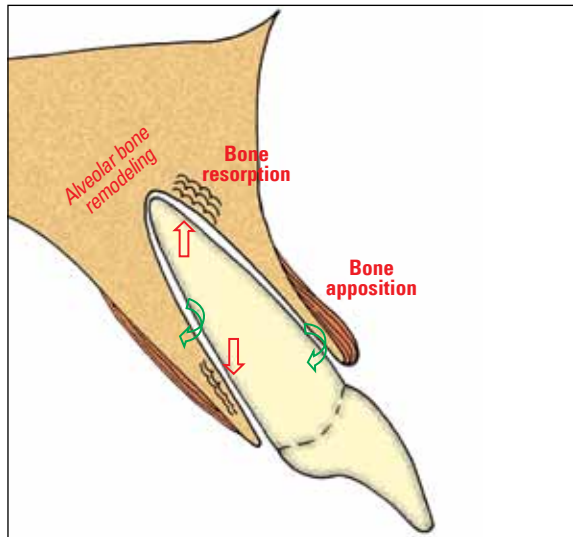


FIGURE 4 - Intrusive mechanics promotes inclination forces due to the natural inclination of the roots of single-rooted anterior teeth. Bone resorption on the periodontal surface takes place along periodontal ligament compression areas (straight arrows) and bone apposition takes place along the area where fibers are being stretched (curved arrows), including the buccal periosteal interface. Bone deflection and deformation also induce or accelerate alveolar bone remodeling promoting a new position of the tooth inside the alveolus in relation to the other elements, creating an intrusive effect.

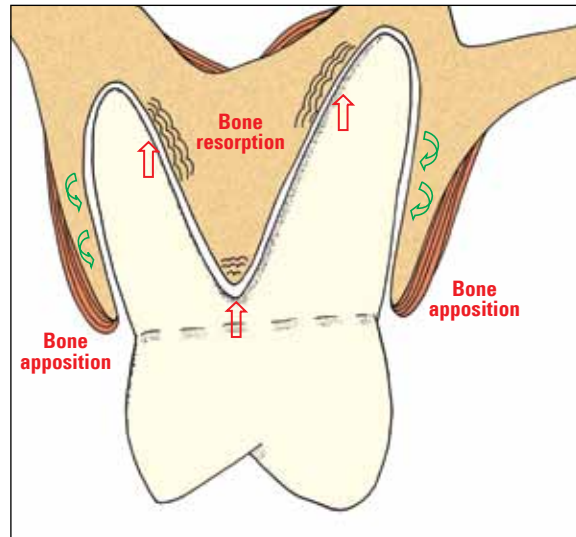


FIGURE 5 - Intrusive mechanics induces inclination forces due to the natural inclination from the cervical emergence of multi-rooted teeth. Bone resorption on the periodontal surface occurs in areas of periodontal ligament compression (straight arrows), while bone apposition takes place in the area where fibers are being stretched (curved arrows), including along the buccal periosteal interface. Bone deflection and deformation also stimulate or accelerate alveolar bone remodeling, promoting a new position of the tooth inside the alveolus in relation to adjacent elements, creating an intrusive effect.

buccal and lingual cortical ridges bone deflections induce the formation of new bone layers underlying to the periosteum in these areas.

Human pathology, when analysing the formation of new cortical or subperiosteal layers as a reactional phenomenon, commonly refers to it as Garrè's Osteomyelitis, a terminology that should be exchanged by Ossifying Periostitis (Figs 2, 4 and 5). This picture neither represents an osteomyelitis nor was described in the literature by Garrè, as it is thought sometimes.

PRIMARY AND SECONDARY BONE TISSUES: DISTINCT FUNCTIONS AND FEATURES

Bone tissue may be classified according to its formation as primary or secondary. Primary

bone tissue is also known as embryonic or even immature bone. Its synthesis is performed by young and recently differentiated osteoblastic cells, which rapidly deposit a randomly distributed matrix to fill up and occupy spaces with bone tissue.

Trabeculae formed by primary bone are short, rhomboid and rich in osteocytic cells, with numerous osteoblasts superficially arranged in palisade. Trabeculae distribution in the primary bone tissue tends to be irregular or random, with the major function of filling up spaces originally occupied by blood clot, granulation tissue and young connective tissue. Meeting mechanical functional demands of a given area is not within the main attributions of primary bone tissue.

From the structural point of view, primary bone is characterized by low mineral density degree and great regeneration and remodelling capacities. Primary bone represents a very important tool for the organism to rapidly refill spaces resulting from fractures, bone surgeries and teeth alveoli after extractions. Once this recovery role has been accomplished by the primary bone, it is gradually replaced by secondary bone.

Secondary bone is also known as adult or mature bone. Its major function is to supply mechanical functional demands. In order to make it happen, it uses its constant remodelling capacity to adapt the structures to forces and other stimuli. Structures will be thinner, delicate or thick and robust according to the frequency and intensity of stimulus. This input may increase or decrease trabeculae density, forming bone structures that can be more or less sclerotic. Cortical plates may vary in thickness in order to adapt to local functional demands.

Bone remodels itself regardless of mechanical input, although forces may accelerate this turnover. Constant bone remodelling is related to its mineral apposition function, maintaining calcium blood levels within the normal range to the overall tissue cell metabolism. Calcium represents the most important ion in our cell metabolism; since it is vital to the organism, its availability levels in the blood should be kept constant at all cost.

PERIODONTAL LIGAMENT: INTERNAL ALVEOLAR PERIOSTEUM

On the alveolar ridge bone surface periosteum is not as organized as in other bones. The periosteal role is played by the periodontal ligament, a highly organized connective tissue membrane containing a delicate, detailed and intricate collagen fiber arrangement (Fig 3). Periodontal ligament functionally connects root surface cementum to the bundle bone that

comprises the innermost wall of the alveolar cortical ridge.

Out of the overall periodontal volume, 50% are blood vessels, most of which are very permeable and thin walled venules. Periodontal ligament thickness ranges from 0.2 to 0.4 mm, with an average thickness of 0.25 mm.

Periodontal collagen fibers attach to the cementum by merging or in continuity to this tissue, that is collagen-based and stratified in lamellas parallelly displayed along the root's long axis. In the same way, periodontal collagen fibers fuse and merge to the bundle bone organic component that lines the internal alveolar surface.

Just like the collagen fibers and the periodontal vascular network, the ligament presents a basket-like structure comprised of epithelial rests of Malassez, with threads 4 to 8 epithelial cells thick and 20 cells in length. The role of these rests lies in maintaining a minimum concentration of epithelial growth factor (EGF) in the periodontal ligament so that the alveolar surface is constantly stimulated to resorb itself and to maintain the average periodontal ligament space. EGF is one of the local factors that stimulate bone resorption under physiologic conditions.

Whenever periodontal fibers are stretched, this is reflected over the external part of the alveolar bone, promoting the formation of new layers of subperiosteal bone (Figs 4 and 5). As soon as it happens, alveolar bone strain, deflection, or deformation take place where the tooth is being inclined or pulled. This phenomenon has therefore an orthopedic nature in the context of concepts that distinguish it from orthodontic phenomena.

BUNDLE BONE: THE MOST EXTERNAL ROOT COMPONENT

Cementum is deposited over the root surface in lamellar layers between which alternated apposition basophilic lines remain, and

many cementoblasts that end up embedded in the matrix and start to be called cementocytes. In the inner part of the cementum, gaps where cementocytes or cementoplasts lie are spider shaped and have numerous small channels filled by cytoplasmatic prolongations. Cementocytes look for a network intercommunication system through their extensions, particularly along the apical half of dental roots.

Cement, periodontal ligament and bundle bone have the same embryonic origin: Dental follicle or sac. Dental follicle presents itself as a tissue package of the tooth bud, being a part of it. In the centre of the tooth bud, lay the enamel organ and the dental papilla; the dental follicle establishes an interface with the surrounding bone structures.

The innermost part of the dental follicle originates the cementum and the most external part originates the bundle or alveolar bone, which covers and lines the dental alveolus internal surface, merging with the alveolar ridge's mature bone in a fully erupted tooth. The intermediate part of the dental follicle forms the periodontal ligament.

Microscopically, the structure of the bundle bone is similar to the cementum, although it is roughly disorganized. It presents with lamellar shaped apposition lines with periodontal collagen fiber bundles, that welds onto the inner surface. Apposition lines and periodontal fiber attachments create a bundle-like structure, with volumes or bands when this tissue is assessed under light microscopy, which justifies the name bundle bone.

Bundle bone can be considered as the plaster or liner of the dental alveolus originated from the tooth bud ectomesenchyma. In other words, the external part of a tooth from the morpho-functional point of view is made of bundle bone that stretches itself without any interface with the mature bone of the alveolar ridge.

By and large, almost all bone formed in em-

bryos and fetuses has the typical structure of primary bone, and therefore, its name: Embryonic or immature bone. As movements and interaction with the external media gradually take place, remodelling also happens and it assumes the arrangement of mature, adult or secondary bone. Primary bone tissue only remains along tendon attachments and dental alveolus in the human skeleton. Not by chance, those are areas that require constant attachment and reattachment of collagen fiber bands in order to meet continuous functional demands. Along tendons and periodontal ligament, frequent and intense forces require a faster turnover of connective tissue attachment.

This faster turnover of periodontal tissue in relation to the other connective tissues in the body, together with bundle bone faster remodelling process, help to cope with the local functional demand. It allows periodontal collagen fibers to be renewed and constantly attached and reattached, mitigating forces that hit the periodontal ligament. But even so many forces are able to deform, deflect or distort bone shape to the extent where subperiosteal tissues are stimulated to appose newly formed bone layers on top of the underlying cortical.

INCLINATION MOVEMENT IN INTRUSIVE MECHANICS

In orthodontic movements, inclination-inducing forces promote the compression of the periodontal ligament by the tooth over the alveolar surface. This compression happens by displacing the extracellular matrix, deforming the cytoskeleton of periodontal components and partially obliterating blood vessels. Cellular stress and eventually the discrete inflammation, promote an increased release of local mediators that stimulate bone remodelling. Tissue reorganization and reconstruction will occur without root resorption and at the expenses of frontal bone resorption on the alveolar surface (Fig 3).

Excessive compression of periodontal ligament may promote cell migration — or even cell necrosis — to neighboring areas, leaving the extracellular matrix isolated and without renewal, this gives it a hyalinized aspect. If cementoblasts are destroyed, in the reconstruction of the area, root resorption may be observed before local full repair. Periodontal ligament compression — instead of focally disorganizing the periodontal ligament and promoting frontal bone resorption — promotes great hyaline areas that, cell free, will suffer a peripheral reconstruction of the compressed area from outside inwards, far from where the phenomena should take place since the very beginning. Remodeling due to distance or peripheral bone resorption may generate an area with undesirable contours, shape and height from an anatomical standpoint.

Periodontal ligament has a very organized distribution of its fiber bundles in order to soften ordinary forces of intrusive nature. The morphologic pattern of the periodontal ligament is not prepared to efficiently neutralize lateral forces and/or inclination of the tooth inside the alveolus. Proof of the difficulty to naturally distribute lateral or inclination forces is in the very possibility of moving teeth orthodontically: Instead of dissipating and absorbing orthodontically applied forces, periodontal tissues reorganize themselves in order to adapt to the stimulus. The application of forces for lateral movements requires moderation and control since excessive forces may induce root and bone lesions because of excessive or morphologically uncontrolled resorption of mineralized tissues.

INTRUSION MOVEMENTS VERSUS INTRUSIVE MECHANICS

Periodontal ligament and its collagen fiber bands are finely prepared to receive and dissipate forces applied parallel to the root long axis. From the physiologic point of view, it absorbs intrusive forces and in orthodontic therapy,

even under intensive forces, intrusion does not simulate either in complexity or in intensity the sum up of masticatory forces. Despite its average thickness is around 0.25 mm, not even the strongest of masticatory loads can compress the periodontal ligament in the apical third, and harm the neurovascular bundle that penetrates the pulp or promote tooth necrosis.

In orthodontic clinical practice, no mechanics are found to use solely intrusive forces, specific and parallel to the root long axis or even perpendicular to the alveolus bottom. The so called intrusive mechanics applied might lead to this effect, although the forces that promote those effects are not intrusion but rather inclination forces (Figs 4 and 5). For a better understanding of this reasoning one should recall the absence of orthodontic devices that apply forces on the long axis of roots, especially if tooth positioning inside the dental alveolus and root inclinations in relation to the crown (Figs 4 and 5) are kept in mind, especially in multi-rooted teeth.

Whenever intrusive forces are applied, even if only in animals and on an experimental basis, those forces do not include inclination forces, as depicted by the Figures 4 and 5. Root inclinations from its cervical emergence, lead experimental pure intrusion forces, in angles perpendicular to the occlusal surface of molar teeth, to cause inclination forces over the roots. In these experimental works,^{2,4,5,9} whenever resorptions are microscopically noticed, they are located on apical regions and buccal surfaces, facing the bifurcations.

Besides orthodontic effects of inclination forces on periodontal tissues during the mechanics known as intrusive, the intrusive effects, to some extent, may be explained through the regional orthopedic stimulus towards resorption represented by forces over the bone at the expenses of periosteal and endosteal tissues. Periosteum has the capacity to react to stimuli or long lasting low intensity injuries through the

formation of new bone layers over the cortical surfaces, which means in the cortical periodontium interface (Figs 2 to 5). This reaction capacity can modify the bone shape, increasing its volume and thickness.

Low intensity input promotes the apposition of new bone layers as periodontal ligament stress areas suffer straining of the fibers attached to the bundle bone during orthodontic treatment. Periodontal ligament primarily represents the alveolar surface periosteum and is very similar to the latter in the reaction capacity.

Alveolar process bone deflection induced by forces is capable of changing the final shape of jaws, since remodeling causes tissues to change in order to meet the new functional demands. Subperiosteal cortical resorption and apposition may take place on the external part of the alveolar processes where teeth are being intruded (Figs 4 and 5), what can also happen along the internal surfaces of the sinus walls and nasal cavity. This same phenomenon on endosteal surfaces changes and rearranges bone trabeculae, its spatial distribution, as much as thickness and length.

Intruded teeth in intrusive mechanics are repositioned in relation to the bone as a role and other teeth, due to orthodontic and orthopedic nature stimuli applied. Tooth structure may well suffer root resorption, as periodontal tissues may be altered in shape and height, without changing biologic widths of periodontal tissues and without affecting the biological feasibility of pulp tissues.

Intrusive mechanics promotes a special rearrangement of the bone in relation to the tooth by means of so called orthopedic phenomena and teeth are concomitantly repositioned by means of inclination forces. As a result of this

synergy, teeth assume a new bone position and a new position in relation to its neighboring elements in the dental arch.

CONCLUSIONS

Bone has great reaction and adaptive capacity towards functional demands. Endosteal and periosteal surfaces stimuli may lead to the resorption and formation of new layers. The long lasting low intensity injuries to the periosteum induce the formation of new layers and may increase the overall bone volume and change its outer contours.

In intrusive mechanics, the natural inclination of roots causes dental movements to be of inclination. Concomitantly to promoting compressive forces in some areas of periodontal ligament of teeth undergoing this type of mechanics, it induces stress and bone deflection forces in other areas and, extensively, in the surrounding bone. These effects also involve external surfaces, since bone thickness on the alveolar process is reduced and may lead to the formation of new layers, including the most cervical portion of the alveolar crest.

An alveolar remodeling of orthodontic nature associated to internal and external bone changes also take place in the intrusive mechanics (Figs 4 and 5), meeting the demands of forces with orthopedic features. The intrusive effect after the alleged intrusive mechanics may be the result of the alveolar remodeling induced by inclination forces and volume changes due to subperiosteal bone formation on the external surface of the alveolar process. It is very likely that accurate imaging studies may capture this subperiosteal phenomena in future works involving patients and using high accuracy CT scans after the application of intrusive mechanics.

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Interview with Stephen Yen

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- Diplomate, American Board of Orthodontists.



Dr. Stephen Yen was born in Boston and lived in different parts of Asia during his childhood. His mother, Chin-Ho Yu Yen, was a physician and his father, Peter Kai-Jen Yen, an orthodontist who taught at Harvard for twenty five years. His parents taught Dr. Yen about faith, family and work as they served two terms as Christian missionaries in Taiwan and Hong Kong. Dr. Yen's father was a pioneer in the field of orthodontics and founded departments in Taipei, Hong Kong, Xian, Chengdu, Shanghai, Beijing and Guangzhou. Dr. Yen graduated from the Harvard School of Dental Medicine before completing his Orthodontic Residency at the University of Southern California. While completing his PhD at the Center for Craniofacial Molecular Biology where he currently conducts research, Dr. Yen worked for two years with Bill Shaw at Children's Hospital Los Angeles, and later took over the care of the craniofacial patients at the hospital. At USC, he teaches orthognathic surgery to the oral and maxillofacial surgery residents and takes part on the joint seminars between the orthodontic and oral surgery departments. He also works one day per week at the USC-Los Angeles County Hospital treating adult patients who need reconstructive surgery due to trauma. He directs a post-residency fellowship in craniofacial orthodontics. His research interests include surgical-orthodontic treatments for cleft lip and palate patients and molecular determinants of facial overgrowth. He is married to Christine Kuida and has three children: Leia, Daniel and Lauren. They add humor, affection and unpredictability to his daily life.

Luciane Macedo de Menezes

First of all I would like to congratulate you for the abnegation and brilliance with which you are engaged in the research of new therapeutic techniques and in assisting patients with severe congenital deformities. The closing of the alveolar cleft with autogenous donor sites such as the iliac crest or the chin region, among others, is well established. Taking that into account, what would be your choice of treatment in the presence of large oronasal communication in the hard palate region, considering patients in mixed or permanent dentition?

Roberto Rocha

I work with a craniofacial team that has surgeons from different disciplines — speech pathologists, pediatricians, geneticists, nurses, child psychologists, pediatric dentists and audiologists — who help to determine what type of treatment is feasible for each patient. During early mixed dentition, we may obturate a large anterior palatal fistula to improve speech. Currently, we are testing the use of Nance appliances in order to provide patients with an appliance that does not have to be remade every few months. Our surgeons may opt to first try to close a fistula using soft tissue flaps from the cheek, tongue or free tissue grafts from other parts of the body with blood supply. However, one potential problem with soft tissue flaps is post-treatment expansion that can re-open the fistula during expansion. A narrow arch form with a large anterior palatal fistula is very challenging to treat. In the past, we have collapsed cleft segments in order to graft the segments so that they could be expanded by distraction osteogenesis to provide additional bone and soft tissue. We have also distracted segments of palatal bone across a palatal opening by using a tooth or a palatal microimplant (TAD) as a

handle for osseous transport. This requires making custom transpalatal wires for the tooth or TAD to travel across a palatal opening.

Distraction osteogenesis to lengthen the mandible in patients with congenital deformities can lead to poor occlusion and open bite. In order to compensate for problems that occur during lengthening, orthodontic intermaxillary elastics can be used to guide the distracted mandibular segment. It is reported that some clinicians remove the distractor before total bone consolidation to take advantage of the phenomenon called “callus molding”. Is it necessary to remove the distractor before bone consolidation to better mold the regenerated bone? Eduardo Franzotti Sant’Anna

Eduardo Franzotti Sant’Anna

The “floating bone technique” describes the early removal of distractors so that the distraction segments can be guided into occlusion with orthodontic elastics.

Since the center of the distraction site is fibrous, distraction osteogenesis is an elastic process. If the distractors are removed too early, then the segments can relapse to its original position. In animal experiments, we found that early removal of distractors could also cause the distraction site to buckle in a transverse dimension and cause midline shifts. If the distractors are to be removed for callus molding, then it should be done after at least two weeks of bone consolidation, so that there can be some stabilization of the distraction site. Heavy force elastics are needed to guide the distraction process. The forces must be continuous to prevent rapid formation of bone across the distraction site. Intermittent force will lead to early consolidation and interrupt the distraction process. We tend to get some relapse so I overcorrect the malocclusion (Fig 1).



FIGURE 1 - Pre-distraction (A, D), after distraction (B, E), after distraction and orthodontic guidance (C, F).

Do you have a specific protocol (time to start, with or without the distractor in place, type of maxillary archwire, elastic force used and time to stop when the open bite does not close) for callus molding?

Eduardo Franzotti Sant'Anna

If you do not remove the distractor, then orthodontic guidance can begin as early as the distraction period. If the distractors are to be removed for callus molding, then the distractors should be left in place at least for two weeks of bone consolidation. Our animal studies suggest that callus molding can occur after two weeks, but the rate of correcting an opening will slow down and may result in only a partial correction while the distraction site is mineralizing. We are balancing opposite needs: Stabilizing the distraction site for bone formation vs. maintaining some elastic properties of the distraction site for open

bite correction. Heavy stainless steel rectangular archwires are used with heavy elastics in order to guide a distraction procedure.

What could be the deleterious effects of re-directing and manipulating the distraction site (callus molding) with orthodontic elastic forces? Eduardo Franzotti Sant'Anna

Since heavy elastic forces are needed to guide distraction procedures, there is always the risk of extruding the tooth out of bone when heavy elastics are placed against brackets and wire. The extrusion effect may come later, after an open bite is corrected, but the osseous segment is relapsing while the bite is held together only by the use of elastics. An initial skeletal correction can turn into a dental compensation as the segments pull away from teeth and relapse. This is a paradigm for distraction, protraction

and surgical relapse that we are investigating. In order to produce skeletal movements and limit skeletal relapse, we add microimplants (TAD) to the orthodontic guidance protocol so that wire loops will connect the brackets and wire to the bone. When orthodontic elastics are applied to the archwire, the force will also be applied against the microimplant in bone.

What is your experience with distraction osteogenesis in grafted areas? Carlos Alberto Estevanell Tavares

It is possible to distract a bone graft, but the quality of the bone graft may not be ideal for distraction. For example, if there are voids or dips in the level of the bone graft at the distraction site, then these irregularities will be stretched out during the distraction process. The ideal bone for distraction is dense, has ideal height and width and does not contain sutures.

Do you believe that BMP grafts represent a promising future for the cleft palate patients? Carlos Alberto Estevanell Tavares

Bone morphogenetic proteins will have a place in craniofacial surgery in the future but the long-term complications need to be identified and understood. We are moving away from alveolar bone grafts from the iliac crests to a combination of BMP2 in demineralized bone matrices. This bone substitute can eliminate the morbidity of harvesting bone from the iliac crest. In a study reported at IADR and ACPA this year (2011), we compared autogenous bone grafts and MP2/demineralized bone matrices. BMP2, as sold in the original collagen sponge, can be compressed in the cleft site and produce only limited amounts of volumes of bone. In order to maintain the space and volume, the BMP2 was placed inside a roll of demineralized bone. We studied the graft outcomes with the Kodak 3000 which has the highest resolution for a cone beam CT and a limited field of three teeth (Fig 2).

We found that neither type of graft completely filled the cleft site but BMP2 with demineralized bone matrices produced almost twice as much bone. Interestingly, both types of bone grafts can show 100% bone fill in the vertical and mesial-distal dimensions as seen in an occlusal radiograph but only 20-60% bone fill in the missing transverse dimension. We need to do better in the future.

In your opinion, what are the main indications for skeletal anchorage in cleft palate patients? Luciane Macedo de Menezes

I use microimplants differently than most orthodontists because I am not trying to eliminate the surgery. Most craniofacial patients will need surgery to improve their function and appearance. The microimplants are used to support surgeries and limit surgical complications. Skeletal anchorage can help to protract a maxilla, widen a fused maxilla, set up a wire system for osseous transport and provide anchorage in edentulous spaces.

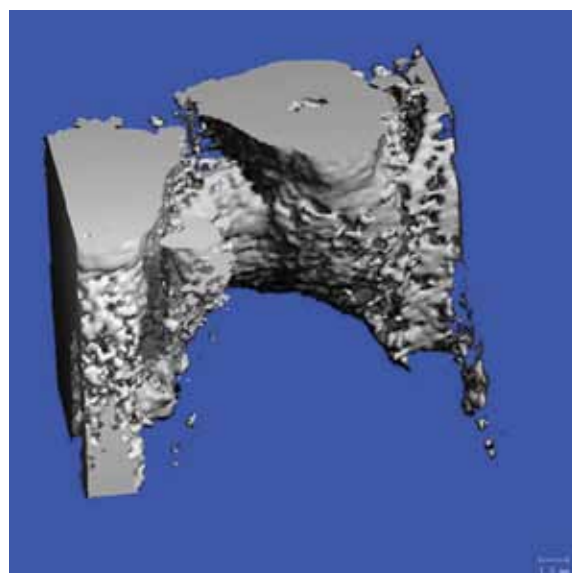


FIGURE 2 - Cone beam computed tomography (CBCT) of alveolar bone graft.

Do you think skeletal anchorage can reduce the use of corticotomies? Carlos Alberto Estevanell Tavares

I think corticotomies and skeletal anchorage can be used together. In terms of anchorage for tooth movement, corticotomies are a method for reducing resistance to tooth movement whereas microimplants (TAD) can increase resistance. Both methods can target specific teeth. The combination of techniques provides a way to alter the bone biology of tooth movement. This is an area of active research for us, as well as several other laboratories.

Basically, in which situations would you recommend:

- **Orthodontic tooth movement associated to corticotomy?**
- **Surgically assisted block displacement?**

Roberto Rocha

I am a little afraid of losing bone during a corticotomy procedure which is why, I believe,

periodontists place a bone graft over the dental roots to hold the space for bone remineralization. Most of the time, I use osteotomy-assisted tooth movement for reshaping the arch form in craniofacial patients (Figs 3 and 4). I ligate the segments against the host bone for three days to ensure a good distraction callus before distracting the segments into position. Corticotomy-assisted tooth movement is used by some orthodontists to accelerate tooth movement. In the future, there may be less invasive ways to produce the bone response needed to accelerate tooth movement.

What are the main challenges in treating children with congenital malformations?

Luciane Macedo de Menezes

I think the main challenges for the future are financial and educational.

One challenge is to make the medical and orthodontic care affordable to patients with congenital malformations through private and government medical insurance programs.

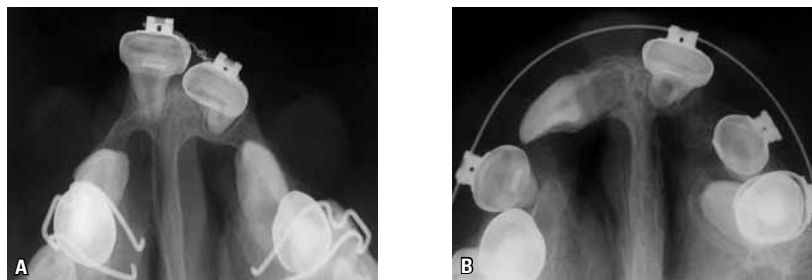


FIGURE 3 - Osteotomy-assisted tooth movement facilitates difficult tooth movements.



FIGURE 4 - Pre-corticotomy (A), reshaping of dental arch with buccal corticotomies (B), post-corticotomy (C).

Another challenge is to help orthodontists to take care of patients with specialized needs through a post-residency fellowship such as the one we have in craniofacial orthodontics at Children's Hospital Los Angeles.

Since the 50's the treatment protocol of cleft lip and palate patients has evolved and several paradigms have changed. From your point of view what new boundaries are to be unfolded in orthodontics and surgery?

Roberto Rocha

Certain innovations such as distraction osteogenesis and bone morphogenetic proteins have provided new strategies for dealing with osseous deformities. However, as an orthodontist, one paradigm that has changed for me is my approach to the Class III malocclusion. I used to be afraid that any procedure that might worsen a Class III malocclusion would automatically lead to orthognathic surgery later in the life of the patient. Currently, I don't worry about Class III malocclusions as much because we now use several maxillary protraction protocols during adolescence to achieve Class III correction even in large skeletal Class III cases. These protraction techniques are supported by alternating expansion and constriction to loosen the sutures, SARPE/LeFort I surgeries in cases of fused sutures and microimplants to limit side effects of treatment. The benefits for early interventions used to be weighed against the post-treatment effects on

maxillary growth. The timing of an alveolar bone graft is such an example. In the past five years, the calculation of risks and benefits for different procedures has changed for me because I have a way to deal with Class III malocclusions without orthognathic surgery. The goal in my research is to re-create the bone response for distraction osteogenesis and rapid tooth movement in order to eliminate or limit the need for surgery. I welcome collaborations with colleagues in Brazil to help studying these new areas of research.

During the period that I had the opportunity to accompany you at Children's Hospital, the affection and dedication provided not only to the cleft children but also to their parents called my attention. I would like to know what was the most important lesson taken from your contact with these children and their parents?

Luciane Macedo de Menezes

As a clinician, I tend to focus on the anatomical and functional problems but I have learned from my patients that the most important part of a person is who they are inside. Perhaps, the hardest task is to help children develop cheerful and positive personalities despite the physical challenges they may have. I feel that as orthodontists we can serve as mirrors to help children see themselves as very special people, made in the image of God.

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An evaluation of the influence of gingival display level in the smile esthetics

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Abstract

Objective: The aim of this study was to evaluate the influence of the amount of gingival display on smile esthetics. **Methods:** Two extraoral photographs were used: One of the close-up smile and one frontal view of the smiling face of four individuals (one Caucasian and one Afro-Brazilian man, and one Caucasian and one Afro-Brazilian woman). The photographs were manipulated in a computer and five images were created for each original photograph with different degrees of gingival display: 0 mm, 1 mm, 3 mm, 5 mm and 7 mm. Then the images were evaluated by 60 individuals who assigned a score from zero to ten to each image on a visual analogue scale. **Results and Conclusions:** Statistical analysis and results showed that levels of gingival display equivalent to 0 mm and 1 mm received the highest mean scores, i.e., 6.6 and 6.2, respectively, and showed no statistical difference between them ($p>0.05$). Gingival displays of 3 mm, 5 mm and 7 mm received lower, decreasing scores of 5.0, 3.5 and 2.9, respectively, without any statistical difference between levels 5 mm and 7 mm ($p>0.05$). Furthermore, the use of close-up photographs of the smile or frontal view photographs of the smiling face showed no statistical difference ($p>0.05$).

Keywords: Esthetic dentistry. Gingiva. Orthodontics. Smile.

Editor's abstract

The smile is a key factor in the composition of an individual's overall beauty. Hence, it's noticed the modern society's growing demand for beautiful, healthy smiles. Several parameters are available to assess smile esthetics, such as the midline, buccal corridor, incisor width/height ratio, incisor crown inclination, gingival contour and amount of gingival display. In the last decade orthodontists have shown a remarkable tendency to treat their patients focusing on improving their smile esthetics. However, although literature cites a wide range of clinical opinions regarding

what would be an ideal or acceptable degree of gingival display, most lack scientific evidence. Indeed, few studies have researched, evaluated and compared different degrees of gingival exposure.

This way, the aim of this study was to assess and compare the degree of esthetic acceptance of five levels of gingival display on smiling and to investigate whether or not there are any differences, in this evaluation, between frontal view extraoral photographs of the smile and close-up smile photographs. Two extraoral photographs were used (one of the close-up smile, Fig 1; one frontal view of the smiling face, Fig

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FIGURE 1 - Example of how the manipulated images of close-up smiles were laid out.



FIGURE 2 - Example of how the manipulated images of smiling faces were laid out.

2) and intraoral frontal views of four individuals, two Afro-Brazilians (one man and one woman) and two Caucasians (one man and one woman). The photographs were manipulated with Adobe® Photoshop® creating different levels of gingival display (0, 1, 3, 5 and 7 mm). The images were randomly assembled then printed on photographic paper and gathered in a photographic album. Sixty individuals, among whom there were orthodontists, oromaxillofacial surgeons and laypersons, were asked to rate the images. Along with the album, each examiner received a form containing a printed simulation of rulers (visual analogue scales), one for each image. They were asked to mark on these rulers with an "X" the degree of esthetic quality associated with each image. Results showed that levels of gingival display equivalent to 0 mm and 1 mm were assigned the highest mean scores, i.e., 6.6 and 6.2, respectively, and showed no statistical difference between them ($p>0.05$). Gingival displays of 3 mm, 5 mm and 7 mm received lower, decreasing scores of 5.0, 3.5 and 2.9, respectively, without any statistical difference between levels 5 mm and 7 mm ($p>0.05$). Furthermore, the use of close-up photographs of the smile or frontal view photographs of the smiling face showed no statistical difference ($p>0.05$).

Questions for the authors

1) To what do the authors attribute the low scores assigned to the photographs in general? Do you believe that this may have influenced the results?

In this type of study absolute values are not a relevant factor, but rather a comparison between the different scores assigned to the variable being investigated (amount of gingival display) as well as between the different groups of raters. Thus, we believe that the "low" values had not influenced on the results.

The highest mean scores found in this study were 6.6 and 6.2 for the group with no gingival display and the group with 1 mm display, respectively. On a scale of 0 to 10, one perceives that these values were not high, thereby demonstrating that these images had not reached high scores from an esthetic point of view. Among the factors to which these low score values can be ascribed, the following stand out: The level of attractiveness of the individuals photographed, the type of image manipulation used, the different groups of raters, the cultural influence of esthetic standards^{1,2} and, especially, the subjective factor inherent in esthetic evaluation. In fact, the old popular saying "beauty is in the eye of the beholder"

influenced the absolute values, but did not influence the comparisons between the images, main purpose of the investigation.

2) Was there disagreement in the assessment among laypersons, orthodontists and surgeons?

Perception varied according to the different levels of gingival display. The results showed that gingival displays of 0 mm and 1 mm yielded no statistically significant difference between the raters, disclosing a similar esthetic perception amongst them ($p>0.05$). In view of 3 mm, 5 mm and 7 mm displays, surgeon behavior was statistically similar to that of orthodontists, whereas the group of laypersons showed statistical differences insofar as it assigned higher scores than the orthodontists in all contexts ($p<0.05$).

Moreover, in general, the laypersons assigned the highest scores while orthodontists were more "stringent" in their assessment and assigned the lowest scores.

These differences as well as the behavior of the raters are better elucidated in another study available in the literature.³

3) Could a 3 mm gingival display be considered the boundary between treatment with or without orthognathic surgery?

In keeping with what was explained above, the "beauty" factor is rather subjective. Therefore, a value of 3 mm of gingival exposure should not be used as a touchstone in deciding whether treatment should be performed with or without orthognathic surgery.

We invite the reader to take a moment to ponder the following: "How many beauty models and actresses have 3 mm or more gingival display on smiling?"

Some adjectives used in the literature, such as "ideal," "acceptable" and "pleasant" defy interpretation. To give you an example, 3 mm gingival display received a mean score of 5.028, i.e., 50%. It is obvious that, as mentioned earlier, an absolute value such as a 5.0 score can hardly characterize a 3 mm gingival display. However, some authors have found that a gingival

display of up to 3 mm, or even 4 mm, is construed as acceptable.^{4,5} The key point, again, is the comparison between the different levels of gingival display and not any absolute score values per se. Moreover, due to differences between the mean scores of 0 mm and 1 mm, and the 3 mm score, and between the latter and the 5 mm and 7 mm scores, one could well argue that a 3 mm gingival display occupies an intermediate position, with the first groups being rated as superior to the last groups.

Therefore, it is a moot question whether or not a 3 mm gingival display, or even a 5 mm or 7 mm display, is unsightly, since characterizing a smile as esthetic or unaesthetic depends on many other factors. This explains why certain national and international beauty models display their gum on smiling but even so their smiles are not considered unpleasant.

Two other crucial factors combine to underpin any clinical decision in favor of or against an ortho-surgical treatment: 1) The etiology of the "gummy" smile, and 2) The patient's chief complaint, because all efforts must be undertaken to ascertain that the orthodontic results meet the patient's expectations.

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An evaluation of the influence of gingival display level in the smile esthetics

Larissa Suzuki*, André Wilson Machado**, Marcos Alan Vieira Bittencourt***

Abstract

Objective: The aim of this study was to evaluate the influence of the amount of gingival display on smile esthetics. **Methods:** Two extraoral photographs were used: One of the close-up smile and one frontal view of the smiling face of four individuals (one Caucasian and one Afro-Brazilian man, and one Caucasian and one Afro-Brazilian woman). The photographs were manipulated in a computer and five images were created for each original photograph with different degrees of gingival display: 0 mm, 1 mm, 3 mm, 5 mm and 7 mm. Then the images were evaluated by 60 individuals who assigned a score from zero to ten to each image on a visual analogue scale. **Results and Conclusions:** Statistical analysis and results showed that levels of gingival display equivalent to 0 mm and 1 mm received the highest mean scores, i.e., 6.6 and 6.2, respectively, and showed no statistical difference between them ($p>0.05$). Gingival displays of 3 mm, 5 mm and 7 mm received lower, decreasing scores of 5.0, 3.5 and 2.9, respectively, without any statistical difference between levels 5 mm and 7 mm ($p>0.05$). Furthermore, the use of close-up photographs of the smile or frontal view photographs of the smiling face showed no statistical difference ($p>0.05$).

Keywords: Esthetic dentistry. Gingiva. Orthodontics. Smile.

INTRODUCTION AND LITERATURE REVIEW

The smile is a key factor in the composition of an individual's overall beauty. Hence, it's noticed the modern society's growing demand for beautiful, healthy smiles. Within this context, orthodontics plays a role of paramount importance.

Several parameters are available to assess smile esthetics, such as amount of gingival display, midline,

buccal corridor, incisor width/height ratio, incisor crown inclination, gingival contour and smile arch appearance, among others.^{13,19} Among these parameters, one should highlight the importance of assessing the amount of gingival display on smiling as it may be related to several factors, such as vertical maxillary excess, upper lip hyperactivity and length, and height of the clinical crowns of maxillary incisors.¹⁶

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The literature comprises classifications for different types of smiles based on the relationship between the upper lip and the anterosuperior teeth. Smiles fall into five different categories: Class I, when the edge of the lip lies above the cervical portion of the incisor crowns ("gummy" smile); class II, when the edge of the lip is located at the cervical third of the incisor surfaces; class III, when the edge of the lip lies in the middle third of the incisor surfaces; class IV, when the edge of the lip is located at the incisal third of the incisors; and class V, when the edge of the lip covers the entire incisor surfaces. The authors concluded that more than 98% of the sample was in classes I and II.²⁴

Another method of smile classification employs degrees of dental crown exposure and gingival tissue display, which fall into three categories: High, medium and low. In the high smile there is total exposure of the clinical crowns of anterosuperior teeth and a continuous strip of gingival tissue. The medium smile reveals most (75%) or all (100%) of the clinical crowns of anterosuperior teeth and the interdental or interproximal papillae, only. The low smile shows less than 75% of the clinical crowns of anterosuperior teeth and no display of gingival tissue.^{17,25}

Photographic models and individuals regarded as having good facial esthetics exhibit, on smiling, the entire length of the anterosuperior teeth and often a narrow strip of gingival margin.⁶ This is precisely the key issue discussed in the clinical and scientific literature. Can the display of gingival tissue on smiling be considered esthetic? If yes, what is the ideal amount of gingival display? Or else, how much exposure would be acceptable?

According to the literature, the appropriate relationship is one in which the upper lip rests on the gingival margin of the central maxillary incisors.^{2,11,14} Likewise, in the so-called ideal smile the upper lip should be positioned so as to expose the entire crown of the maxillary in-

cisors and up to 1 mm of gingiva.^{1,4,9,10} On the other hand, up to 3 mm of gingiva display can be considered esthetically acceptable.^{5,12,13}

The literature also reports the difference in the amount of gingival display on smiling between genders. Several authors agree that women have a higher smile line with greater gingiva display, while men have a lower smile line.^{3,4,12,18,20,21,25}

The "gummy" smile is not necessarily unaesthetic to the public's eye. Some movie stars and models, especially women, display some gingival tissue on smiling but their smile is nevertheless still considered pleasant.¹⁶ Moreover, the smile pattern varies with patient age, with children displaying a greater amount of gingiva than adults. It is noteworthy that with advancing age, loss of tissue tone causes the upper lip to stretch and upper teeth to overlap, thereby reducing gingival display.³

Another influencing factor is ethnicity, as Afro-descendants tend to display less of their upper teeth and gingiva, probably due to the shape and volume of their lip muscles.² In contrast, a study that investigated six different clinical variables, including amount of gingival display in 253 patients from six different ethnic groups, found that the Afro-descendant group had the greatest amount of gingival display.¹⁸

Another recently raised question suggests that the method used to assess the smile can potentially influence the results. In a research study using different images, i.e., a frontal view photograph of the face, a photograph depicting the lower third of the face and a close-up dental view, the authors found that after the images had been evaluated by a group of laypersons the esthetic impact was lower in the facial pictures. In other words, the influence of global facial esthetic factors had masked how the smile was perceived and evaluated.⁸

According to Sarver²² in the last decade orthodontists have shown a remarkable tendency to treat their patients with a focus on improving

their smile esthetics. However, although the literature cites a variety of clinical opinions regarding what would be an ideal or acceptable degree of gingival display, most lack scientific evidence. Indeed, few studies have researched, evaluated and compared the different degrees of gingival display.

Kokich Jr et al¹³ evaluated, among other esthetic criteria, the perceived amount of gingival display using photographs of smiles intentionally altered on a computer. Variations in the distance between the upper lip and the gingival margin of maxillary incisors were created, generating five types of close-up smile images: 2 mm of the incisors overlapped by the lips, lips touching the gingival margin of the incisors (0 mm of gingival display), 2 mm, 4 mm and 6 mm of gingival display. The images were subjected to three groups of raters consisting of orthodontists, laypersons and general practice (GP) dentists. The smiles with the upper lip touching the gingival margins of the incisors (0 mm) were generally assigned the highest scores. When the groups of raters were separated, laypersons and GP dentists considered displays of up to 4 mm acceptable while orthodontists rated displays above 2 mm as unpleasant.

Hunt et al,¹² in a similar study, manipulated two photographs (one of a man and one of a woman) and created seven types of relations between lips and teeth, ranging from 2 mm to 4 mm, i.e., in the first, the upper lips overlapped the crowns by 2 mm and the last had a gingival tissue display of 4 mm. Then the images were evaluated by 120 laypersons. The results showed that gingival display in the 0 mm group received the highest scores while displays above 2 mm received progressively lower scores.

The literature has discussed the use of anatomic references for characterizing the smile. However, many esthetic parameters are based on the clinical perception of some authors or on subjective assessments whereas the standards supported by scientific research have not yet been established in Brazil. Therefore, it should be stressed

that there is a need for studies aimed at determining the ideal gingival display on smiling according to the esthetics of the Brazilian population, whose composition is rather heterogeneous.

In view of the above, the aim of this study was to assess and compare the degree of esthetic acceptance of five levels of gingival display on smiling (0 mm, 1 mm, 3 mm, 5 mm and 7 mm) using manipulated photographs, and to investigate whether or not there are any differences, in this evaluation, between frontal view extraoral photographs of the smile and close-up smile photographs.

MATERIAL AND METHODS

Two extraoral photographs were used (one frontal view of the smile, one of the close-up smile) and intraoral frontal views of four individuals, two Afro-Brazilians (one man and one woman) and two Caucasians (one man and one woman) aged between 20 and 30 years, totaling eight photographs altogether.

The photographs were taken by the same operator with a digital Canon Rebel camera, Canon MR-14 ring flash and Canon macro lens 100 (Canon Inc., Taiwan). The eight photographs of the smiles of all individuals were manipulated in Adobe Photoshop® 7.0 (Seattle, WA, USA).

In manipulating the images, the teeth and gingiva were erased from the smile photographs as depicted in Figure 1A. Subsequently, the image from the previously taken frontal view intraoral photograph was inserted into the smile photo and then manipulated (upwards or downwards) to create different levels of gingival display (Fig 1B, C). With this purpose, an adaptation of the method described by Peck et al²⁰ was performed, as shown in Figure 2. Initially, two points were created, i.e., subnasale, corresponding to the upper border of the philtrum of the lip in the midsagittal plane; and the upper lip point, corresponding to the lower border of the philtrum of the lip just above the lip vermilion border. These points served as reference to draw a vertical line corresponding to the



FIGURE 1 - Illustration of the method to standardize the creation of manipulated images.

midsagittal plane. Two horizontal lines were then drawn, one tangent to the superior most gingival margin of the central incisors and one tangent to the inferior most contour of the upper lip, both perpendicular to the vertical line. Finally, as illustrated in Figure 1C, the central image was moved upwards or downwards according to the horizontal reference lines, and the distances in millimeters were recorded to create the images.

In the images of close-up smiles, measurements made in millimeters were used at a 100% ratio, i.e., 1 mm on the image was equivalent to 1 mm in reality. Thus, five images were generated according to the following criteria:

- » 0 mm gingival display: Gingival margin of maxillary central incisors positioned in the lower contour of the upper lip.
- » 1 mm gingival display: Gingival margin of maxillary central incisors positioned 1 mm below the lower contour of the upper lip.
- » 3 mm gingival display: Gingival margin of maxillary central incisors positioned 3 mm below the lower contour of the upper lip.
- » 5 mm gingival display: Gingival margin of maxillary central incisors positioned 5 mm below the lower contour of the upper lip.
- » 7 mm gingival display: Gingival margin of maxillary central incisors positioned 7 mm below the lower contour of the upper lip.

The five photographs of each individual — generated from JPEG format files with 300 dpi resolution and 25 cm x 38 cm size — were randomly distributed on the same page (Fig 3).

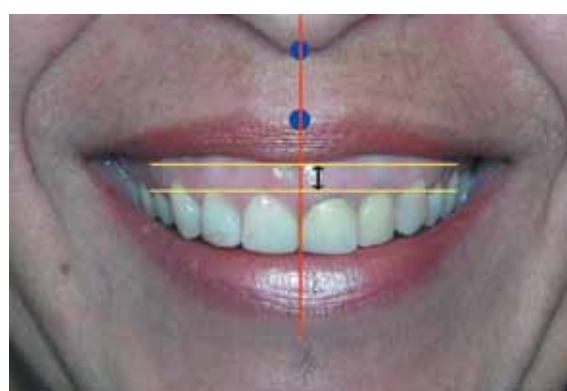


FIGURE 2 - Illustration of the method to create images with different levels of gingival display.

For facial photographs, measurements in millimeters were calculated at a 25% ratio, i.e., 1 mm on the image was equivalent to 4 mm in reality. Thus, five images were generated for each existing photograph, adopting the same criteria described before. The images were also randomly distributed and saved in files with the same features of the close-up smile photographs (Fig 4).

Subsequently, these files were processed in a specialized digital lab using professional equipment, model Noritsu 2901 (Noritsu Brazil S/A, Manaus, AM), on Kodak Edge Generations paper (Kodak Brazil, Manaus, AM) with photographic quality on standard A3 size paper (29.7 cm x 42 cm). A photographic album with eight pages containing all images was then made and the four pages containing the facial images were then randomly ordered and followed by the four pages with the close-up smiles.



FIGURE 3 - Example of manipulated images of close-up smiles.

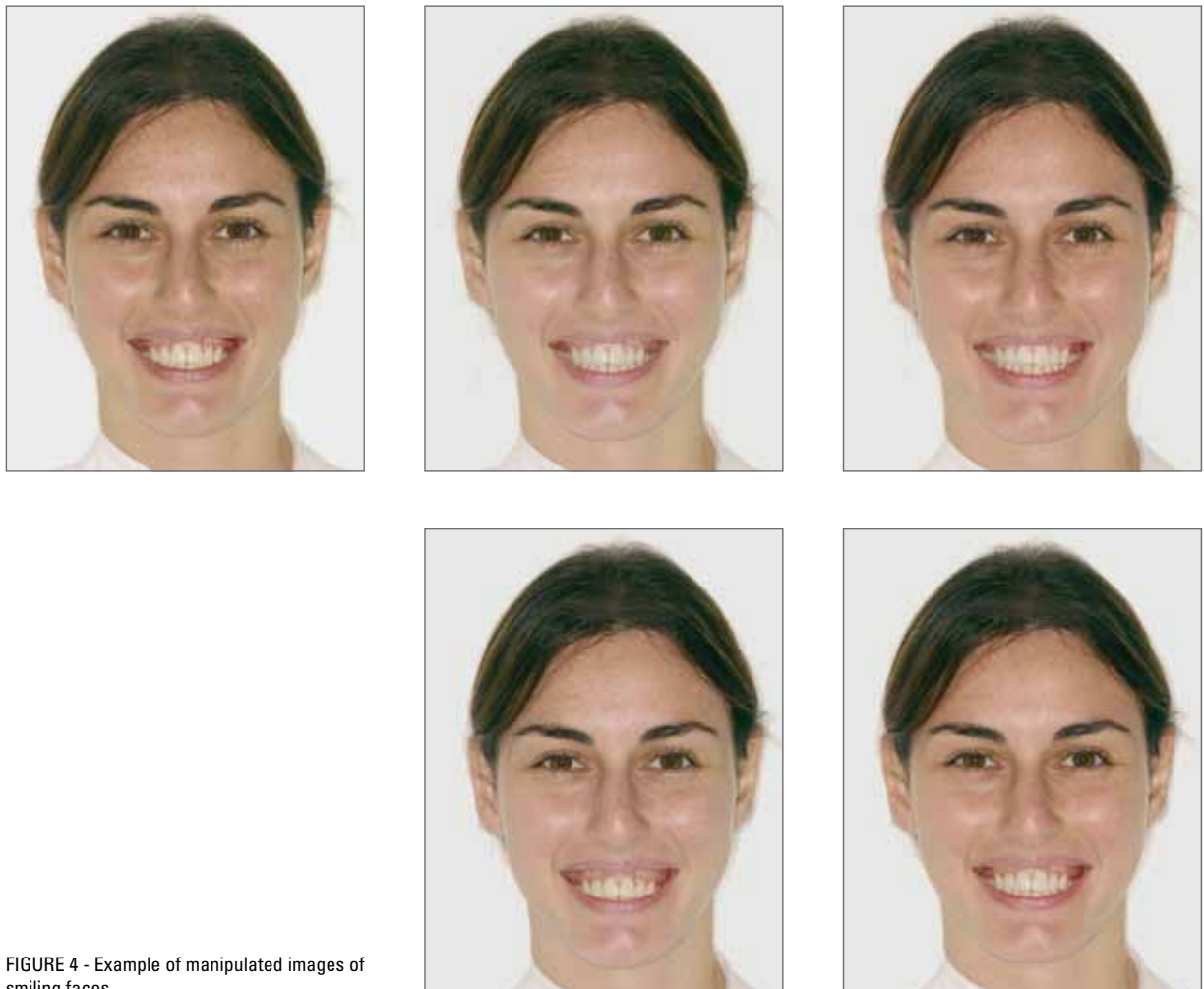


FIGURE 4 - Example of manipulated images of smiling faces.

After the album was ready, 60 individuals, among them orthodontists, oromaxillofacial surgeons and laypersons were asked to rate the images.

Along with the album, each examiner received a printed form containing a printed simulation of a ruler (visual analogue scale) for each image (5 rulers per page, totaling 40 rulers). On these rulers they were asked to mark with an "X" the quality degree associated with each image. The scale was designed to show an ascending order of quality from right to left. It was explained to each rater that it was possible to place a mark anywhere on the ruler. The visual analogue scale^{15,17,26} had 10 cm, and a dash was drawn at its center, giving raters the perception of regular quality. The distance (in mm) between the mark made by the rater and the point on the far left served as an estimation of the degree of quality determined for each image rated.²³ At the end of the evaluation process, a total of 40 images were examined by each rater.

The data were statistically analyzed, central tendency and dispersion were calculated, and normal distribution tested (KS test). ANOVA and Tukey's test were also applied with significance level of 5% in order to identify differences among the groups.

RESULTS

Table 1 and Figure 5 show that, regardless of the photograph type, smiles with 0 mm, 1 mm, 3 mm, 5 mm and 7 mm gingival display had mean scores of 6.6, 6.2, 5.0, 3.5 and 2.9, respectively. Between the scores assigned to the smiles with 0 mm and 1 mm display, no statistically significant difference was found. Likewise, no statistically significant differences were found between smiles with 5 mm and 7 mm gingival display. A gingival display of 3 mm, on the other hand, differed from the other levels, as did the gingival displays of 5 mm and 7 mm, to the detriment of the others.

In comparing the assessments made of the close-up smile images with those of frontal view smiles it becomes clear that no statistically significant difference exists between the scores assigned to any degree of gingival display ($p>0.05$). For close-up smiles and frontal view smiles, respectively, the top scores were once again given to the 0 mm degree of display, namely, 6.6 and 6.5, while the 7 mm display received the lowest scores, i.e., 2.9 and 2.9 (Table 2).

To test the influence of ethnicity and gender the data were submitted to ANOVA ($p<0.05$). Table 3 and Figure 6 show the means and confidence intervals associated with the degree of gingival display in all images evaluated according to ethnicity and gender of individuals.

For the smiles with 0 mm gingival display, the overall mean scores assigned to the Caucasian

TABLE 1 - Mean and overall standard deviation of scores of different types of smiles.

Gingival Display	Mean Score	SD
0 mm	6.6*	1.976
1 mm	6.2*	1.819
3 mm	5.0	1.926
5 mm	3.5**	1.764
7 mm	2.9**	2.590

* No statistical difference found between 0 mm and 1 mm displays ($p>0.05$).

** No statistical difference found between 5 mm and 7 mm displays ($p>0.05$).

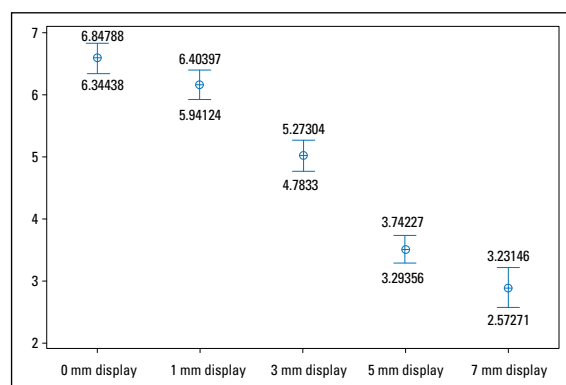


FIGURE 5 - Mean and confidence interval of scores of different types of smiles.

man, Afro-Brazilian man, Caucasian woman and Afro-Brazilian woman were 5.7, 6.7, 6.7 and 7.3, respectively. For the smiles with 1 mm gingival display, the overall mean scores assigned to the same groups were 5.7, 5.9, 5.9 and 6.9, respectively. For the 3 mm display, the mean scores were 4.6, 4.8, 4.9 and 5.7, respectively. For the 5 mm display, 3.3, 3.0, 3.6 and 4.2, respectively. Finally, for the 7 mm display, the mean scores were 2.5, 2.2, 3.2 and 3.8, respectively.

At all levels of gingival display the scores assigned to the Afro-Brazilian woman were higher than all others. However, this result was only statistically significant for the 1 mm gingival display. For the 0 mm and 3 mm displays, the Afro-Brazilian woman received significantly higher scores than the Caucasian man. For the 5 mm and 7 mm displays, however,

this difference was seen among Caucasian and Afro-Brazilian men ($p < 0.05$). The results were similar in all other scenarios.

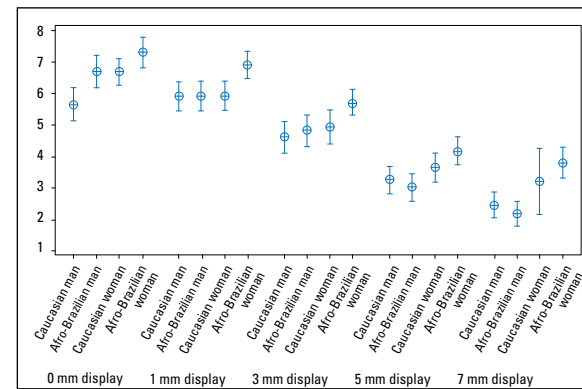


FIGURE 6 - Mean and confidence interval for scores of all images at different levels of gingival display, according to the groups under study (gender and ethnicity).

TABLE 2 - Mean scores and standard deviations in assessments of close-up smiles and frontal view smiles.

Gingival Display	Image Type	Mean Score	SD	p
0 mm	Close-up Smile	6.6	2.113	= 0.658
	Frontal Smile	6.5	2.409	
1 mm	Close-up Smile	6.4	2.032	= 0.52
	Frontal Smile	6.0	2.152	
3 mm	Close-up Smile	5.2	2.053	= 0.103
	Frontal Smile	4.9	2.279	
5 mm	Close-up Smile	3.4	2.057	= 0.158
	Frontal Smile	3.7	2.04	
7 mm	Close-up Smile	2.9	2.145	= 0.922
	Frontal Smile	2.9	4.037	

TABLE 3 - Mean and standard deviation of scores in different groups of individuals.

Gingival Display	Groups	Mean Score	SD	Conclusions
0 mm	1 - Caucasian man	5.7	2.018	
	2 - Afro-Brazilian man	6.7	1.978	(2 = 3)
	3 - Caucasian woman	6.7	1.677	(4 > 1)
	4 - Afro-Brazilian woman	7.3	1.893	
1 mm	1 - Caucasian man	5.9	1.770	
	2 - Afro-Brazilian man	5.9	1.891	(1 = 2 = 3)
	3 - Caucasian woman	5.9	1.764	(4 > 1, 2, 3)
	4 - Afro-Brazilian woman	6.9	1.692	
3 mm	1 - Caucasian man	4.6	1.941	
	2 - Afro-Brazilian man	4.8	1.900	(1 = 2 = 3)
	3 - Caucasian woman	4.9	2.113	(4 > 1)
	4 - Afro-Brazilian woman	5.7	1.571	
5 mm	1 - Caucasian man	3.3	1.651	
	2 - Afro-Brazilian man	3.0	1.662	(1 = 2 = 3)
	3 - Caucasian woman	3.6	4.2	(4 > 1, 2)
	4 - Afro-Brazilian woman	1.878	1.681	
7 mm	1 - Caucasian man	2.5	1.613	
	2 - Afro-Brazilian man	2.2	1.605	(1 = 2 = 3)
	3 - Caucasian woman	3.2	4.102	(4 > 1, 2)
	4 - Afro-Brazilian woman	3.8	1.889	

DISCUSSION

Evaluation of all images showed that among the levels of gingival display researched, the highest scores were assigned to the group with no gingival display (0 mm) and 1 mm display, i.e., 6.6 and 6.2, respectively. These two types showed no statistically significant difference between them, in agreement with the literature, which also assigns the highest scores to a 0 mm gingival display.^{12,13} The argument found in the literature that a variation of up to 1 mm gingival display is imperceptible further corroborates these findings.^{10,20} This result also confirms the idea that, on smiling, the proper relationship is one where the upper lip rests on the gingival margin of the maxillary central incisors, which is represented by the group with 0 mm gingival display.^{2,11,14}

The literature also argues that gingival display of up to 2 mm is esthetically acceptable.^{3,12} Although this study did not include a group with 2 mm gingival display, but only 1 mm and 3 mm, it can still be inferred, given the proximity of these values and the results achieved, that a 2 mm gingival display would be acceptable.

For the smiles with 3 mm, 5 mm and 7 mm gingival display, the overall mean scores assigned were 5.0, 3.5, and 2.9, respectively. All these values were noticeably below the 0 mm and 1 mm gingival display levels ($p < 0.05$). Moreover, these values slowly decreased, i.e., the larger the display, the less esthetic the smile became. Furthermore, given the similarities between the 5 mm and 7 mm display groups, one could suggest that from a certain point onwards, perception of unsightliness becomes a constant.

One striking feature that raised some doubt was the low scores assigned by the raters. The highest scores found in this investigation were 6.6 and 6.2, for levels 0 mm and 1 mm, respectively. On a scale of 0 to 10, one realizes that these values were not high, thereby demonstrating that the images were not up to standard from

an esthetic point of view. Moreover, the main goal was not to evaluate the quality of images individually, but rather to compare the different levels of gingival display on smiling. Among the factors responsible for the low scores, one could highlight (a) the individual esthetics of the subjects, who had different smile patterns, and (b) image manipulation, which can produce lower quality images than the original photos.

Some adjectives used in the literature, such as “ideal,” “acceptable” and “pleasant” are difficult to interpret. As an example, the 3 mm gingival display received an average score of 5.028, i.e., 50%. It is obvious that, as mentioned earlier, an absolute value such as a 5.0 score can hardly qualify a 3 mm gingival display. However, Castro⁵ found that a gingival exposure of up to 3 mm is considered pleasant. The question then is whether or not a 5.0 score may be considered esthetically acceptable or even if this degree of exposure may or may not be considered unpleasant. Moreover, due to differences between the average scores of 0 mm and 1 mm, and the 3 mm score, and between the latter and the 5 mm and 7 mm scores, one could well argue that a 3 mm gingival display occupies an intermediate position, with the first groups achieving higher scores than the last groups.

Therefore, it is a moot question whether or not a 3 mm gingival display, or even a 5 mm or 7 mm display, are unpleasant, since qualifying a smile as pleasant or unpleasant depends on many other factors. This explains why certain Brazilian and international beauty models display their gingiva on smiling but even so their smiles are not considered unpleasant.

This study also focused on evaluating image manipulation of two types of photographs, close-up smiles and smiling faces. However, the results showed no statistically significant difference between them ($p > 0.05$). This indicates that evaluation of smile esthetics, in a full view of the face (including nose, hair, eyes, face contours, etc.) or a

close-up view, highlighting only the smile, affords the same degree of perception, suggesting that the face has no bearing on the esthetic evaluation of different levels of gingival display. This result is in disagreement with the literature, whose assessments of the facial photographs showed a decrease in the level of perception.⁸ This study, however, did not assess the influence of gingival display on smiling using manipulated photographs, but rather the esthetic impact of three photographs types of 18 smiling individuals.

On the other hand, a more detailed evaluation of Table 2 shows that the 3 mm display, despite statistical similarities with the values found, points to a different tendency. In other words, it appears that since the 3 mm display constitutes a boundary or turning-point between “esthetic” and unaesthetic, the photographs types may have influenced the evaluation. A more detailed interpretation of these results would require further studies with more numerous images and raters.

Although this was not among the aims of this study, the potential influence of gender and ethnicity on the evaluations of different degrees of gingival display was also investigated. At all gingival levels investigated, the Afro-Brazilian woman received the highest scores. From a statistical point of view the differences did not follow a pattern, as the scores assigned to the Afro-Brazilian woman were higher than those of the Caucasian man with 0 mm and 3 mm

gingival display, and higher than the scores assigned to the Caucasian and Afro-Brazilian man with 5 mm and 7 mm gingival display. These results should be analyzed with caution, as the findings do not indicate that the Afro-Brazilian woman’s smile is more beautiful than the others or that the smile of the Caucasian or Afro-Brazilian man is less attractive. It is worth mentioning again that, since this study utilized a sample comprising four individuals and their manipulated images, intrinsic variables complicate the analysis of some absolute values involved, such as individual esthetic and image manipulation technique.

Thus, the study underscores the need for further research with the inclusion of a larger sample and different ethnic groups.

CONCLUSIONS

It can be concluded that the 0 mm and 1 mm degrees of gingival display exhibited the highest mean scores, and no statistical difference was found between them ($p>0.05$). Degrees of gingival display 3 mm, 5 mm and 7 mm were considered less esthetic and received lower, decreasing scores.

Moreover, it was found that the use of smile close-up photographs or frontal facial smiling photographs exerted no influence on the esthetic perception of raters in their judgment of the different smile patterns ($p>0.05$).

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Dentoskeletal changes in Class II malocclusion patients after treatment with the Twin Block functional appliance

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Abstract

Objective: This prospective clinical study evaluated dentoskeletal changes in Class II malocclusion patients after treatment with the Twin Block functional appliance. **Methods:** The treatment group consisted of 19 subjects (mean age 9.5 years) and the control group consisted of 19 subjects (mean age 9.9 years) situated before pubertal growth spurt. Unpaired Student's t test showed the sample homogeneity at the beginning of the study. Initial (T1) and one year follow-up (T2) cephalometric radiographs were obtained for all subjects. Wilcoxon test and Mann Whitney test were used to evaluate changes intra and inter groups from T1 to T2. **Results:** A Class I molar relationship was achieved in 15 subjects of the treated group while no modification occurred in the control group. No significant effect was observed either in the maxilla or in the vertical pattern. A significant increase in total mandibular length and an anterior displacement of the mandibular position occurred in the treated group ($p<0.05$) as well as an overjet reduction, influenced by significant upper incisor retroclination and lower incisor proclination ($p<0.05$). **Conclusions:** Class II treatment with the Twin Block appliance in Brazilian patients showed skeletal and dental effects, including increase in mandibular length and incisors compensation, respectively.

Keywords: Class II malocclusion. Functional appliance. Growth.

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Editor's abstract

Facial profile and balance are directly influenced by the growth of facial bones. In case of disharmony between maxilla and mandible, orthodontic treatment during the pubertal growth spurt may reposition and improve their relation. Functional orthopedic appliances can be cited among the appliances that deliver orthopedic manipulation. The Twin Block (TB) is a specific functional appliance used in Class II mandibular deficiency treatment. Several studies in the literature had already assessed its effectiveness, but the samples were based on European and North American populations. Therefore, a question arises: "Would the results be the same in the Brazilian population?"

Based on this premise, the authors' proposal with the present study was to assess maxillo-mandibular skeletal and dentoalveolar changes with Twin Block (Fig 1) treatment in a Brazilian sample. A prospective randomized clinical study was then conducted with a sample involving 38 patients. Sample selection was based on the following inclusion criteria: Skeletal Class II ($ANB > 4^\circ$); Class II molar relationship; overjet >6 mm, and absence of previous

orthodontic treatment. The included individuals were in the phase preceding the prepubertal growth spurt. After the sample selection, it was randomly divided into two groups: The TB group, with 12 boys and 7 girls and the control group (CG), also with 12 boys and 7 girls. Cephalometric radiographs were obtained at the beginning of the study (T1) and after one year follow-up (T2). Wilcoxon and Mann Whitney tests were used to assess changes intra and intergroup from T1 to T2. A molar relationship correction was observed in 80% of the treated patients, while no changes were observed in the control group. No changes were observed in the maxilla or in the vertical growth pattern of the face. A significant increase in mandibular length and an anterior displacement of the mandible were observed in the treatment group ($p < 0.05$), such as an overjet decrease, influenced by significant upper incisors retroclination and lower incisors proclination ($p < 0.05$). The authors concluded that Class II malocclusion treatment with the Twin Block functional appliance presented skeletal and dental effects, including increase in mandibular length and incisors compensation, respectively.

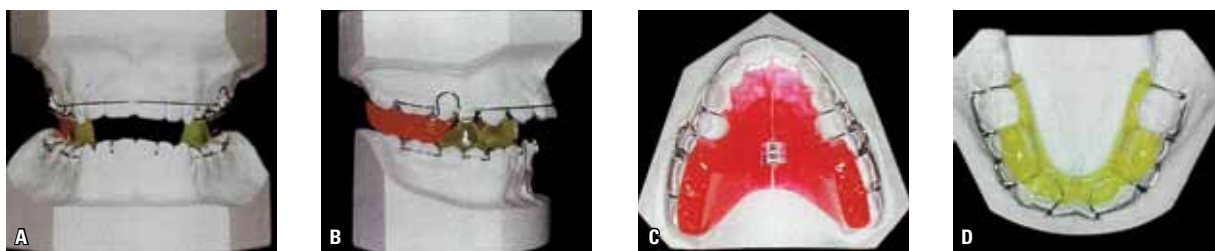


FIGURE 1 - Twin Block appliance design used in this study.

Questions for the authors

1) In the authors' opinion, under the methodological point of view, what are the negative and positive points of this study?

From the authors' point of view, the sample size was consistent, statistics was correct, and the main positive point was the fact that a prospective and randomized study was conducted. Previous systematic reviews showed that few studies used a correct methodology, especially regarding the fact of not being prospective or randomized. A negative point, as in all clinical studies, was related to missing cases of the sample during the follow-up.

2) The authors believe that there would be significant differences in cephalometric measurements at the end of orthodontic treatment and six months after therapy?

This evaluation is already being conducted, with a 10-year follow-up after pretreatment. A pilot study showed no statistical difference between one or two-phase treatment, after

comprehensive orthodontic treatment, agreeing with previous findings, for example those from the University of North Carolina.

3) From the clinical point of view, what are the advantages of using the Twin Block functional appliance instead of extraoral appliances?

Basically, the Twin Block appliance would be more indicated for Class II mandibular deficiency malocclusion, whereas the headgear would be indicated for maxillary excess. In patients presenting severe esthetic deformities due to Class II malocclusion, the Twin Block appliance shows the advantage of improving self-esteem during treatment, since a bite reconstruction is promoted and facial improvement is observed. Clinically, probably due to this fact, a very good cooperation regarding the appliance wear was observed. Moreover, a unique Twin Block characteristic must be highlighted: Because of its separate upper and lower parts instead of a monoblock, it allows mandibular asymmetry corrections through the extension of one of the lower bite blocks.

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Dentoskeletal changes in Class II malocclusion patients after treatment with the Twin Block functional appliance

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Abstract

Objective: This prospective clinical study evaluated dentoskeletal changes in Class II malocclusion patients after treatment with the Twin Block functional appliance (TB).

Method: The sample was divided into two groups with 19 subjects in each: Group TB, with mean age of 9 years and 6 months (sd = 10 months); and a control group, with mean age of 9 years and 9 months (sd = 13 months), both situated before the pubertal growth spurt. Unpaired Student's t test showed the sample homogeneity at the beginning of the study. Initial (T1) and one year follow-up (T2) cephalometric radiographs were obtained for all subjects. Wilcoxon test and Mann-Whitney test were used to evaluate changes intra and intergroups from T1 to T2. **Results:** A Class I molar relationship was achieved in 15 subjects of the TB group, while no modification occurred in the control group. No significant effect was observed either in the maxilla or in the vertical pattern. A significant increase in total mandibular length and an anterior displacement of the mandibular position occurred in the treated group ($p < 0.05$) as well as an overjet reduction, influenced by significant upper incisor retroclination and lower incisor proclination ($p < 0.05$). **Conclusions:** Class II treatment with the Twin Block appliance in Brazilian patients showed skeletal and dental effects, including increase in mandibular length and incisors compensation, respectively.

Keywords: Class II malocclusion. Functional appliance. Growth.

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INTRODUCTION

Class II patients show specific clinical characteristics, such as a large overjet resulting in a soft tissue profile imbalance. This is closely related to patients' and parents' complaints concerning self-image and self-confidence.^{1,2} In order to reestablish their self-esteem, an early approach into correction of the dentoskeletal disharmony and improvement of facial esthetics may be indicated in the pre-pubertal stage, sometimes leading to two-phase orthodontic treatment.³ Although, the controversy regarding the best time of Class II skeletal malocclusion correction still remains.⁴

Interceptive correction of mandibular retrognathism in growing patients requires knowledge concerning the mechanism of functional orthopedic appliances. These appliances may be effective based on the possibility of inducing bone growth. The occurrence of additional mandibular growth during the active phase of treatment and stability of the results are important questions to be addressed.⁵

The Twin Block (TB) appliance is used to promote correction of Class II mandibular deficiency malocclusions. A number of authors⁶⁻¹¹ have already discussed its effectiveness on mandibular changes, overjet and Class II correction in European and American sample, but different populations may have different results using the same appliance.

The aim of this study was to assess the maxillomandibular skeletal and dentoalveolar changes produced by the Twin Block appliance treatment in a Brazilian sample.

MATERIAL AND METHODS

This study was a prospective randomized clinical trial, submitted and approved by the Institutional Ethics Committee, comprised of 38 subjects selected from those attending the Department of Orthodontics (State University of Rio de Janeiro). Screening was based on the

following inclusion criteria: Skeletal Class II (ANB > 4°); molar Class II relationship; overjet > 6 mm (Fig 1A) and no previous orthodontic treatment. Subjects had to be included on pre-pubertal growth spurt phase characterized by: Fishman¹² indicators "1 and 2" of skeletal maturity estimated from 100 to 85% of individual's relative growth rate on the hand and wrist radiograph and confirmed by the "initiation phase" of the vertebral maturation described by Hassel and Farman¹³ on the cephalometric radiograph.

The sample was randomly divided in two groups: the TB group (TBG) included 12 boys and 7 girls (mean age = 9 years and 6 months; sd = 10 months) and the Control group (CG) also included 12 boys and 7 girls (mean age = 9 years and 9 months; sd = 13 months).

Cephalometric radiographs were obtained at the beginning of the study (T1) and after 12 months of observation (T2). They were scanned and digitized using Radiocef 2.0 Memory Studio computer software (Floresta, Belo Horizonte/MG, Brazil). The customized cephalometric analysis used in the study is shown in Figures 2 and 3. A vertical reference line (VL) was constructed perpendicular to sella-nasion through sella to measure anteroposterior position of the first molars.¹⁴

To evaluate the error of the method, 10 pairs of radiographs were randomly selected and digitized by the same operator four times each. An intraclass correlation coefficient (ICC) was calculated to test intra-operator error. Unpaired Student's *t* test was used to check for homogeneity between groups for cephalometric values at T1.

The subjects in the CG did not undergo any orthodontic intervention during the study, but right after this time they were submitted to comprehensive orthodontic treatment at the pubertal growth spurt. The TBG patients used the removable appliance (Fig 1B) in a modified design of the one described by Clark² (Fig 4),



FIGURE 1 - Lateral views of a mandibular retrognathism Class II malocclusion subject.

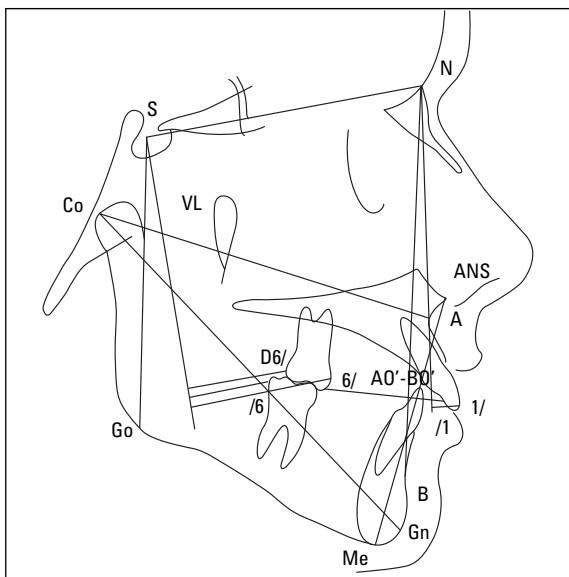


FIGURE 2 - Customized cephalometric analysis: Linear measurements. Co-A: Maxillary length; Co-Gn: Mandibular length; AO'-BO': Wits appraisal; LAFH: Distance from anterior nasion spine (ANS) to menton (Me), anterior facial height; S-Go: Distance from sella to gonion, posterior facial height; 1/NA (mm): Upper incisor-nasion/point A line; 1/NB (mm): Lower incisor-nasion/point B line; U6/VL: Distance from the most anterior point of the upper first molar to vertical line; DU6/VL: Distance from the most posterior point of the upper first molar to vertical line; L6/VL: Distance from the most posterior point of the lower first molar to vertical line.

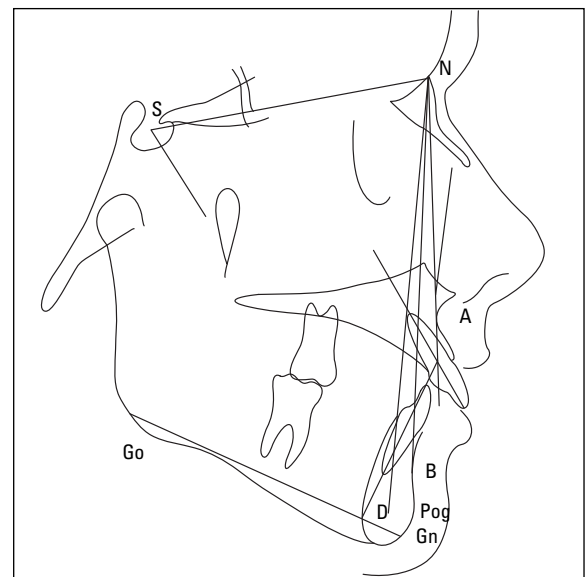


FIGURE 3 - Customized cephalometric analysis: Angular measurements. SNA: Sella-nasion-point A angle; SNB: Sella-nasion-point B angle; SND: Sella-nasion-point D angle; ANB: Point A-nasion-point B angle; NA/APog: Angle formed by nasion-point A and pogonion-point A; GoGn/SN: Angle formed by gonion-gnathion and sella-nasion; SNGn: Sella-nasion-gnathion angle; 1/NA (degree): Upper incisor-nasion/point A line; 1/NB (degree): Lower incisor-nasion/point B line; 1/GoGn: Angle formed by lower incisor and gonion-gnathion; 1/1: Interincisor angle.

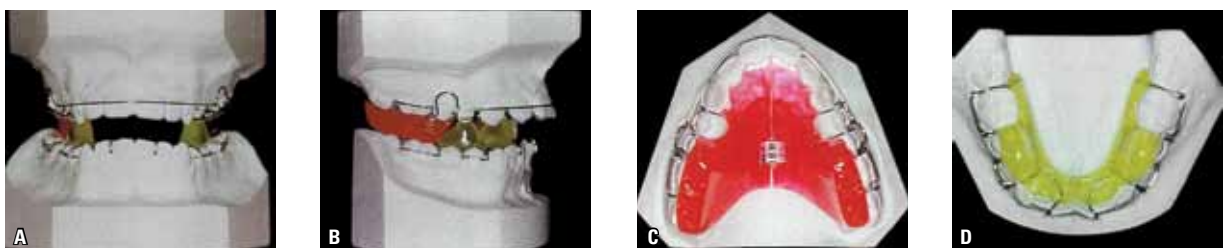


FIGURE 4 - Twin Block appliance used in this study.

and were instructed to wear it continuously except during sports, eating and oral hygiene. The initial construction bite was taken with approximately 4 mm mandible protrusion. A time grid was filled in by the parents, and showed that the appliance had been worn on average for 18 hours and 50 minutes per day.

Descriptive statistics were used to determine the mean and standard deviation of the linear and angular cephalometric values at T1 and T2 for both groups. Wilcoxon test was used to check for statistical differences between T1 and T2 in each group and Mann-Whitney test to evaluate changes resulting from treatment at the end of the observation period (T2) between groups. The confidence level of $p < 0.05$ was used as reference for all statistical tests.

RESULTS

The error of the method demonstrated excellent operator reproducibility, showing ICC values higher than 0.773 for a confidence interval of 95%.

Means, standard deviations and results of the unpaired Student's *t* test of the cephalometric measurements at T1 are shown in Table 1. No statistically significant differences between groups were observed, thus confirming the sample homogeneity at T1.

The molar relationship correction was attained in 15 of the 19 treated patients (80%), while the CG did not show any modification in Class II relationship.

Table 2 shows initial and final cephalometric values of the CG and TBG as well as the results of the Wilcoxon test comparing each group from T1 to T2. Significant increases in mandibular length (Co-Gn= +2.82 mm) and in maxillary length (Co-A= +2.37 mm) occurred in the CG, reflecting the maintenance of the Class II pattern with growth, confirmed by the unaltered ANB. The linear measurements for upper incisor (1/NA: $p < 0.30$) and for upper and lower

TABLE 1 - Cephalometric measurements of CG and TBG at T1 and the *p* values of the results of the unpaired Student's test.

GROUPS Measure- ments	Control (n = 19)		Twin Block (n = 19)		p
	Mean	SD	Mean	SD	
SNA	80.30	4.78	80.96	3.64	0.636
SNB	74.07	3.42	74.39	3.68	0.780
SND	72.40	3.30	71.59	3.23	0.502
ANB	6.24	2.00	6.51	1.66	0.645
1/NA (mm)	4.95	2.90	6.23	2.72	0.170
1/NA (degrees)	26.07	7.70	28.83	6.52	0.241
1/NB (mm)	6.29	2.42	6.31	2.62	0.978
1/NB (degrees)	30.18	5.79	29.62	5.27	0.760
1/I	117.51	10.41	114.92	7.97	0.396
GoGn-SN	35.27	5.13	34.78	5.38	0.773
NA-Pog	11.99	4.93	12.15	3.96	0.913
Co-Gn	107.05	6.29	110.94	4.29	0.089
Co-A	89.22	5.49	92.08	3.46	0.062
1/GoGn	100.83	7.08	100.43	5.43	0.845
LAFH	63.76	4.54	65.61	4.99	0.239
AO-BO	5.77	2.93	6.66	2.99	0.360
SNGn	70.33	3.32	69.78	4.14	0.658
S-Go	69.32	3.62	71.08	3.97	0.164
U6/VL	29.72	5.39	31.47	5.22	0.317
L6/VL	27.12	5.29	28.97	5.51	0.300
DU6/VL	19.04	4.49	20.87	5.21	0.255

TABLE 2 - Cephalometric measurements of the groups at T1 and T2 (n=38) (Wilcoxon test).

	Control Group (CG)								Twin Block Group (TBG)							
	T1		T2		(T2-T1)	SD	p	T1		T2		(T2-T1)	SD	p		
	Mean	SD	Mean	SD				Mean	SD	Mean	SD					
SNA	80.30	4.78	81.46	4.66	1.16	3.05	ns	80.86	3.75	81.57	4.21	0.71	1.54	ns		
Co-A	89.38	5.37	91.74	4.91	2.37	3.18	*	92.08	3.46	95.41	5.47	2.27	3.22	*		
SNB	74.06	3.42	75.20	4.26	1.15	2.71	ns	74.39	3.68	76.22	3.57	1.83	1.32	*		
SND	72.40	3.30	72.78	3.34	0.38	1.26	ns	73.10	3.09	71.60	3.23	1.42	1.31	*		
Co-Gn	10.05	7.52	110.72	6.97	2.82	2.80	*	110.94	4.29	115.81	3.59	5.22	3.26	*		
ANB	6.24	2.00	6.25	1.59	0.02	1.53	ns	6.51	1.66	4.78	2.32	-1.16	0.94	*		
Na/APog	11.99	4.93	12.12	4.62	0.13	3.03	ns	12.15	3.96	9.89	4.31	-2.25	1.98	*		
AO-BO	5.77	2.93	6.71	3.43	0.95	2.79	ns	6.66	2.99	3.57	3.32	-3.09	2.66	*		
GoGn/SN	35.27	5.13	34.94	5.74	-0.32	2.32	ns	34.78	5.38	34.28	4.66	-0.50	2.38	ns		
LAFH	63.76	4.54	64.58	4.57	0.82	2.26	ns	65.61	4.99	69.31	8.79	2.06	2.10	*		
SNGn	70.33	3.32	69.74	4.45	-0.59	2.15	ns	69.78	4.14	68.61	3.58	-0.99	1.52	*		
S-Go	69.32	3.62	70.56	4.59	1.24	2.53	ns	71.08	3.97	73.38	4.68	2.46	3.05	*		
1/NA (mm)	4.95	2.90	5.64	2.44	0.70	1.38	*	6.23	2.72	3.64	2.37	-2.59	2.43	*		
1/NA (degrees)	26.07	7.70	27.42	7.29	1.35	3.30	ns	28.83	6.52	20.47	4.92	-8.36	5.14	*		
1/NB (mm)	6.29	2.42	6.62	2.51	0.34	1.37	ns	6.28	2.63	7.52	2.43	1.25	1.35	*		
1/NB (degrees)	30.18	5.79	31.15	6.86	0.98	3.29	ns	29.62	5.27	33.41	5.00	3.80	3.72	*		
1/GoGn	100.83	7.08	101.00	7.65	0.17	3.40	ns	100.43	5.43	7.52	2.43	2.48	3.67	*		
1/I	117.51	10.41	115.16	11.40	-2.35	5.40	ns	114.92	7.97	33.41	5.00	5.40	5.62	*		
U6/VL	29.72	5.39	32.32	5.72	2.60	4.64	*	31.47	5.22	35.36	10.41	1.45	1.96	*		
DU6/VL	19.04	4.49	21.11	5.56	2.08	4.36	ns	20.87	5.21	22.35	4.65	1.01	1.86	*		
L6/VL	27.12	5.29	29.67	6.26	2.55	4.85	*	28.97	5.51	32.55	5.52	3.51	2.82	*		

first molars (U6/VL and DU6/VL: $p < 0.014$ and L6/VL: $p < 0.04$) also increased statistically. The treatment group showed significant changes in all the cephalometric measurements, except for SNA and GoGn/SN.

In the comparison between the TBG and CG at T2 (Table 3), the most important skeletal findings in the treated group were a statistically significant increase in mandibular length (Co-Gn) and in the

spatial position of the mandible related to the anterior cranial base (SND), and a significant reduction in the measurements related to maxillomandibular sagittal position (ANB, NA/APog = $p < 0.05$, AO-BO = $p < 0.01$). The treated group also showed statistical changes on upper incisors position (1/NA mm and 1/NA degree) and on lower incisors tipping (1/NB degree), which resulted in significant reduction of interincisor angle ($p < 0.01$).

TABLE 3 - Comparison of CG and TBG mean changes between T1-T2 (Mann Whitney test).

Measurements		Control Group (n=19)		Twin Block Group (n=19)		p
		T2-T1	SD	T2 - T1	SD	
Skeletal	SNA	1.16	3.05	0.71	1.54	0.418
	Co-A	2.37	3.18	2.27	3.22	0.708
	SNB	1.15	2.71	1.83	1.32	0.057
	SND	0.38	1.20	1.42	1.31	0.027*
	Co-Gn	2.82	2.80	5.22	3.26	0.020*
	ANB	0.02	1.53	-1.16	0.94	0.008*
	NA/Apog	0.13	3.03	-2.25	1.98	0.002*
	AO-BO	0.95	2.79	-3.09	2.66	0.000*
	GoGn/SN	-0.32	2.32	-0.50	2.38	0.885
	LAFH	0.82	2.26	2.06	2.10	0.091
	SN-SGn	-0.59	2.15	-0.99	1.52	0.418
	S-Go	1.24	2.53	2.46	3.05	0.234
Dental	1/NA (mm)	0.70	1.38	-2.59	2.43	0.000*
	1/NA (degrees)	1.35	3.30	-8.36	5.14	0.000*
	1/NB (mm)	0.34	1.37	1.25	1.35	0.075
	1/NB (degrees)	0.98	3.29	3.80	3.72	0.034*
	1/GoGn	0.17	3.40	2.48	3.67	0.109
	1/1	-2.35	5.40	5.40	5.62	0.000*
	U6/VL	2.60	4.64	1.45	1.96	0.885
	DU6/VL	2.08	4.36	1.01	1.86	0.840
	L6/VL	2.55	4.85	3.51	2.82	0.212

DISCUSSION

Clinically, 80% of the treated group have benefited from the correction of the Class II molar relationship, while no improvement was observed in the control group. As the children were treated before the pre-pubertal spurt, the stability of the correction needs to be checked later on.

The TB treatment did not result in inhibition of maxillary forward growth since no statistical

difference was observed in the TBG (Table 3). These results are in agreement with Lund and Sandler,⁷ while some authors^{8,9,10} have reported slight maxillary restraint suggesting a headgear effect. Change in the position of point A due to upper incisor retroclination may have hidden the effect upon maxilla in this study, affecting SNA and CO-A changes.

The TB appliance was found to have influenced mandibular anterior development when SND was used as reference ($p < 0.05$). In contrast, SNB angle changes did not reflect the same pattern, probably because point B was influenced by proclination of the lower incisors. Previous studies have reported an anterior mandibular displacement related to the anterior cranial base as a result of TB treatment, which means that the mandible was spatially altered in the anteroposterior plane resulting in a correction of Class II malocclusion (Table 3).^{7,8,10,11,16}

A significant increase in mandibular length (Co-Gn=2.4 mm) was observed as well as a significant reduction in intermaxillary sagittal discrepancy (ANB = -1.18°; NA/APog = -2.38°; AO-BO= -4.04 mm), which probably contributed to the Class II correction (Table 3). An increase in total mandibular length was also found by Morris et al⁶ (3.7 mm in 9 months), Lund and Sandler⁷ (2.4 mm/year), Mills and McCulloch⁸ (4.2 mm/year), Toth and McNamara¹⁰ (3.0 mm in 16 months) and Trenouth¹¹ (3.2 mm/year). These results suggest a response of mandibular growth increments, which may be in part justified by a reported good compliance, as the appliance is considered comfortable and esthetic.

No significant changes were observed in the vertical measurements (Table 3), which were expected as a result of the capping effect of the appliance blocks controlling vertical eruption of the molars.² Clinically, it has been demonstrated that the TB maintains the facial pattern.^{2,6,8,9} In some studies,^{7,10} the increase in

facial height has been attributed to a different appliance design that allows molar eruption.¹⁷ Although, molar disocclusion has been mentioned by Clark² as an advantage of the appliance (Figs 1B and 4C) which could be also observed in this sample at the end of the treatment and was considered important in influencing mandibular anterior growth.

The first molars did not show significant linear changes when measured to VL ($p>0.05$) (Table 3). The upper incisors showed significant retroclination ($1/NA= 3.29$ mm, 9.71°); the lower incisors, proclination ($1/NB= 2.82^\circ$) and the interincisal angle, an increase ($1/1= 7.75^\circ$) and these results are in accordance with other authors^{7,8,10,11} who have reported similar findings. The effect on the upper incisors can be mainly attributed to the Hawley arch (Fig 4B) which transmitted a reaction force to the upper incisors. Koroluk et al¹⁸ verified that overjet reduction is favorable in early treatment, considering the high trauma incidence in preadolescents with a Class II Division 1 malocclusion.³ The lower incisor movement may have been due to anchorage loss in response to keeping the mandible in a protrusive position. This effect may be unfavorable in patients where the incisors are proclined before treatment. Therefore, this approach may not be

indicated in such cases or an additional stage of treatment may be required to upright the lower incisors.³

CONCLUSION

The present study assessed changes after a 12-month treatment with the Twin Block appliance, compared to a control group. The analysis of the results leads to the following conclusions:

- 1) Eighty percent of the patients treated with the Twin Block appliance attained Class I relationship.
- 2) A significant improvement occurred in the total mandibular length and anteroposterior relationship.
- 3) Significant retroclination and proclination was observed in the upper and lower incisors, respectively, leading to a decrease in the overjet.
- 4) No statistically significant change was found in molar position in the treated group.
- 5) No effect was observed in the position of the maxilla.

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Relapse of maxillary anterior crowding in Class I and Class II malocclusion treated orthodontically without extractions

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Abstract

Objective: The present study aimed to retrospectively compare the postretention stability of maxillary anterior incisors alignment in Class I and Class II patients. **Method:** Sample comprised 38 patients of both genders, treated with no extraction and Edgewise mechanics, divided into two groups: Group 1 comprised 19 patients, at a mean age of 13.06 years, with Class I malocclusion and initial maxillary anterior crowding greater than 3 mm. Group 2 comprised 19 patients, at a mean age of 12.54 years, with Class II malocclusion, and also with an initial maxillary anterior crowding greater than 3 mm. In the dental casts of pretreatment, posttreatment and postretention, the Little irregularity index, intercanine width and width between first and second premolars, intermolar width and maxillary arch length were measured. For intragroup comparison among the three evaluation times the one-way ANOVA was used followed by Tukey test. Intergroup comparison was performed by independent t test. To verify the presence of correlation, the Pearson correlation test was used. **Results:** Results evidenced greater stability of treatment in Group 2 (Class II), because during the postretention period, a smaller relapse of maxillary anterior crowding in Group 2 (0.80 mm) than in Group 1 (1.67 mm) was observed. **Conclusion:** It was concluded that treatment of maxillary anterior crowding is more stable in Class II malocclusion than in Class I malocclusion.

Keywords: Relapse. Maxillary anterior crowding. Posttreatment stability.

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Editor's abstract

Among the goals to be achieved with the completion of orthodontic treatment, stability is perhaps the most difficult to obtain. Researchers from all over the world have been very dedicated in trying to unravel the etiology of the orthodontic relapse of the mandibular anterior crowding, however little attention has been given when it concerns the maxillary anterior crowding. Based on this premise the authors of the present study had as objective to evaluate the relapse of maxillary anterior crowding in Class I and Class II malocclusion cases treated orthodontically without extractions. For this a sample of 48 orthodontic records of patients treated without extractions who presented initially Class I or Class II malocclusions was selected. All patients were treated with fixed appliances and Edgewise mechanics and initially had a maxillary anterior crowding

greater than or equal to 3 mm according to Little.¹ The sample was divided into two groups according to the initial malocclusion, i.e.: Group 1 - patients with Angle Class I; and Group 2 - patients with Class II malocclusion. The mean postretention evaluation time was 8.6 years for Group 1 and 8.04 years for Group 2. The variables assessed were: Little irregularity index (modified), intercanine, interpremolar and intermolar widths and maxillary arch length. The results demonstrated greater stability of the Class II malocclusion treatment, considering that during the postretention period there was greater relapse of the maxillary anterior crowding in patients with initial Class I malocclusion. With the results obtained it was concluded from this work that the Class I malocclusion treated without extraction is more relapsing than Class II when the maxillary anterior crowding is evaluated.

Questions for the authors

1) Based on the findings of the article, would you indicate different protocols for retention in the Class I and Class II malocclusions?

In theory, as the treatment of Class II malocclusion had become less stable in the long-term, the adoption of a more rigid retention protocol (extending the fixed or removable retention time) is indicated in these cases. However, we observed that the difference between the groups in relation to the amount of maxillary anterior crowding relapse was 0.87 mm. In clinical terms, a difference that tends to be almost insignificant. The clinician should keep in mind that, regardless the type of initial malocclusion, the adoption of more stringent retention protocols will, in most situations, conduct

to long-term stability of the treatments. The patient presenting Class II malocclusion should also be instructed on the importance of their compliance in the use of the retention because of the greater tendency of relapse.

2) The fact that there was greater Little irregularity index in Group 1 (Class I) at the end of treatment can not be related to the outcomes achieved? That is, cases with a better finishing would have lesser tendency to relapse?

We believe not. The relationship between "quality of finishing x orthodontic relapse" is a controversial issue in the literature. It was suggested that the better the quality standard of finishing, the greater the stability of orthodontic

treatment.^{2,3} However, recent studies found no correlation between the quality of finishing and the long-term stability.^{4,5,6,7} The results of correlation tests of this study tend to corroborate these studies. It should be noted that both groups had, at the end of treatment, satisfactory maxillary anterior alignment (Little index of 0.34 mm and 0.00 mm for Groups 1 and 2, respectively). Thus, no groups were compared that can be classified as greatly or badly finished.

3) In your opinion, what would influence maxillary anterior relapse the most: The initial severity presented by the case or the orthodontic outcome achieved?

The authors' opinion, based on this study and related works on the subject, is that both factors have no significant influence on maxillary anterior relapse. Note that individuals with strong initial crowding tend to have a larger amount

of irregularity in postretention, but this fact does not mean that there was a higher relapse. The evaluation of relapse should be based on the relationship between the amount of orthodontic correction and the amount of crowding relapse. For example, a maxillary anterior irregularity postretention of 1.0 mm in a patient with initial crowding of 3 mm would imply in a relapse of 33.3% of the correction achieved (if the treatment is finished with a perfect dental alignment). Moreover, there is also a relapse of 33.3% of the correction in a patient with initial crowding of 6 mm and which has 2 mm of crowding in the postretention. Factors such as the tension of periodontal fibers, presence of rotated teeth in the initial phase, muscular function, relapse of crowding in the opposite arch, time and retention protocol and initial malocclusion (Class I or II) clearly influence the maxillary anterior relapse.

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Abstract

Objective: The present study aimed to retrospectively compare the postretention stability of maxillary anterior incisors alignment in patients with Class I and Class II malocclusions. **Methods:** Sample comprised 38 patients of both genders, treated with no extraction and Edgewise mechanics, divided into two groups: Group 1 comprised 19 patients, at a mean age of 13.06 years, with Class I malocclusion and initial maxillary anterior crowding greater than 3 mm. Group 2 comprised 19 patients, at a mean age of 12.54 years, with Class II malocclusion, and also with an initial maxillary anterior crowding greater than 3 mm. In the dental casts of pretreatment, post-treatment and postretention, the Little irregularity index, intercanine width and width between first and second premolars, intermolar width and maxillary arch length were measured. For intragroup comparison among the three evaluation times the one-way ANOVA was used followed by Tukey test. Intergroup comparison was performed by independent t test. To verify the presence of correlation, the Pearson correlation test was used. **Results:** Results evidenced greater stability of treatment in Group 2 (Class II), because during the postretention period it was observed a smaller relapse of maxillary anterior crowding in Group 2 (0.80 mm) than in Group 1 (1.67 mm). **Conclusion:** It was concluded that treatment of maxillary anterior crowding is more stable in Class II malocclusion than in Class I malocclusion.

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INTRODUCTION

The orthodontic treatment has as main objective the correction of malocclusions, however, these corrections present considerable variation in relation to the postretention stability. Although there is a consensus in the orthodontic literature that some occlusal changes will inevitably occur after the end of orthodontic treatment,^{19,30} it was evidenced that the stability of teeth alignment is highly variable and widely unpredictable.^{2,20} In relation to the scientific approach, despite numerous studies regarding the etiology of the relapse in orthodontic correction of mandibular anterior crowding,^{3,4,11,18} a small number of studies was conducted focusing the post-treatment changes in the maxillary anterior region and the possible factors associated to the magnitude of this relapse.^{9,14,23,27,29}

LITERATURE REVIEW

The stability of orthodontically aligned teeth was found to be highly variable.¹¹ Little¹⁷ and other authors^{20,28,32} concluded that long-term decreases in arch perimeter and length are usual in extraction and non-extraction cases or even in patients who did not undergo orthodontic treatment. Little,¹⁷ in 1990, stated that no clinical finding, dental cast or cephalometric parameter, before or after treatment, seemed to predict the relapse. However, as well as in most studies related to crowding relapse, only the mandibular arch was evaluated. Thus, extrapolation of these findings to the maxillary arch should be restricted.

Maxillary anterior crowding relapse is less prevalent when compared to the relapse in mandibular incisors alignment.^{26,31,32}

After many decades of research, there is a consensus that stability of the aligned teeth is variable and largely unpredictable, particularly in the mandibular anterior segment.¹¹ Surbeck et al²⁹ noted that less than 7% of the patients had severe irregularity on the maxillary anterior teeth in the long-term out of retention.

However, Kahl-Nieke et al¹⁵ found that mean irregularity index of maxillary incisors increases in 23% from post-treatment to postretention.

According to Little,¹⁶ postretention crowding of mandibular incisors is the first evidence of the progressive instability of orthodontic treatment outcomes. Regardless of the relapse etiology, irregularity of the mandibular incisors seems to be the precursor of maxillary crowding, overbite and deterioration of treatment.

In 1994, Sadowsky et al²⁷ studied orthodontic cases previously treated, aiming to evaluate maxillary and mandibular long-term alignment stability. All cases were treated non-extraction with fixed Edgewise appliances and stood without retainers for a minimum of 5 years. Data were obtained from dental casts. The average retention time with a mandibular fixed lingual retainer was 8.4 years. The pre-treatment irregularity index was 8.0 mm in the maxillary arch and 5.2 mm in the mandibular arch; at the end of treatment it was 0.9 mm and 1.0 mm, respectively, and at the postretention stage it was 2.0 mm and 2.4 mm, respectively. The treatment was accomplished without incisor advancement or distal movement of the mandibular molars; however, both arches were transversely expanded. During the postretention stage all variables showed relapse except for the intercanine and interpremolar width in the expanded maxillary arch.

Vaden et al,³² in 1997, quantified changes in tooth relationships in a series of extraction cases at 6 years and again at 15 years postretention. The authors³² concluded that maxillary and mandibular arches became shorter and narrower with age. After 15 years, most (96%) of the maxillary incisors irregularity correction was maintained. In general, 90% of the patients in this study were better off 15 years after treatment than they were before treatment.

Surbeck et al²⁹ assessed dental casts of 745 patients and studied the anterior maxillary teeth

alignment in the pre- (T1) and post-treatment (T2) stages, and also in the postretention stage, aiming to verify the influence of initial crowding amount at the postretention relapse. As a sample selection criterion, it was used the presence of all anterior maxillary teeth in the case of orthodontically treated patients, with or without tooth extraction. The sample was divided into 3 groups, according to the postretention dental casts configuration: One with significant spacing (1); one with significant irregularity (2); and one with perfect alignment (3). Logistic regression analyses revealed that irregularity was associated with greater anatomic contact displacement and with greater incisor rotation both at T1 and T2. Correlation analyses revealed that the pattern of pretreatment rotational displacement has a strong tendency to repeat itself after retention.

Huang and Artun¹⁴ reported that previous studies had suggested a poor association between initial and postretention pattern of incisor irregularity. One explanation may be that the incisor movements are limited by the boundaries provided by the incisors in the opposite arch. If so, postretention displacement of the maxillary and mandibular incisors may be related to the forces exerted by the lips. According to the authors, the positioning of mandibular incisors and lip function could have a greater role at relapse in the buccolingual direction of anterior maxillary teeth than movements performed during orthodontic mechanics. They suggested that the positioning of the mandibular anterior teeth influences the positioning of the maxillary teeth and vice versa and, thus, relapse of the anterior teeth in one of the arches could be associated with the relapse of teeth alignment on the opposite arch.

To test this hypothesis, long-term postretention dental casts of 96 patients, most Class II malocclusion subjects, with acceptable occlusion at the time of appliance removal were examined. Postretention period ranged from 4 to

25 years. Statistical analyses demonstrated a significant association between the overall irregularity of the maxillary and mandibular incisors. The amount and direction of displacement of antagonistic pairs of maxillary and mandibular central incisors were also associated.

Naraghi et al²⁴ investigated the amount and pattern of relapse of maxillary anterior teeth previously retained with a bonded retainer. The study group consisted of 135 study casts from 45 patients. Recordings from dental casts before treatment (T1), at debonding (T2), and 1 year after removal of the retainer (T3) were assessed. All patients had been treated with fixed Edgewise appliances and the incisors irregularity index was calculated in the three groups. The mean irregularity index at T1 was 10.1 mm, at T2 it was 0.7 mm and at T3 it was 1.4 mm. In 42 patients, 55 teeth were corrected more than 20° between T1 and T2, and mean relapse in this group was 7.3°. Regarding alignment of the maxillary anterior teeth, the contact relationship between the laterals and centrals seems to be the most critical. It was concluded that minor or no relapse was noted at the 1-year follow-up.

Erdinc, Nanda and Isiksal⁸ evaluated dental casts and cephalometric records of 98 patients, both genders, who presented Class I and Class II Division 1 malocclusions. They were evaluated before treatment, at post-treatment, and at postretention. The patients were divided into two groups (49 subjects each). Half of them had been treated with extractions, and half were non-extraction treated. There was no statistically significant growth in both groups during the evaluation period. Only the interincisal angle showed a significant difference between the extraction and non-extraction groups. Both groups showed statistically significant decreases in overjet with treatment and no significant postretention relapse occurred. Overbite decreased in both groups, but in the non-extraction group the results were better. However,

statistically significant relapse occurred for both groups. The treatment resulted in statistically significant improvement in the incisors crowding – both maxillary and mandibular – in both groups, and the mandibular incisors showed a significant relapse of this crowding, being, respectively, 0.97 mm and 0.99 mm in groups with and without extractions. Maxillary incisor irregularity relapse was smaller than mandibular incisor relapse for both groups. Clinically acceptable stability was obtained, accordingly to Little.¹⁶ No statistically significant differences were recorded between the extraction and non-extraction groups regarding incisor alignment postretention stability.

Canuto,⁵ compared the long-term stability of maxillary incisors alignment in cases treated with or without rapid maxillary expansion (RME) during orthodontic treatment. The sample comprised 48 subjects presenting Class I and Class II malocclusions, treated non-extraction and with Edgewise fixed appliances. The sample was divided into two groups according to the treatment protocol: Group 1 (with RME) comprised 25 patients at a mean initial age of 13.53 years, who underwent rapid maxillary expansion during orthodontic treatment. Group 2 (without RME) comprised 23 patients at a mean initial age of 13.36 years, treated with fixed appliances and no rapid maxillary expansion. Dental casts measurements were obtained at three evaluation times (pretreatment, post-treatment and postretention) and the variables assessed were Little irregularity index, intercanine, interpremolar and intermolar widths, and maxillary arch length and perimeter. The results evidenced significant transversal increases in the group treated with RME (Group 1), however, during the postretention period, no significant differences were observed between the groups in the amount of maxillary incisors alignment relapse (+1.52 mm in both groups), as well as in most of the variables evaluated. Therefore,

it was concluded that the RME procedure did not influence the long-term maxillary anterior crowding relapse.

Martins²¹ evaluated the influence of RME on maxillary anterior alignment stability in patients treated with premolar extraction. The sample comprised 60 patients of both genders, with Class I and Class II malocclusions, treated with extraction of 4 premolars and Edgewise mechanics. The sample was divided into two groups according to the treatment protocol. Group 1 comprised 30 patients, with initial mean age of 13.55 of years, orthodontically treated by extraction of four premolars. Group 2 also comprised 30 patients, with initial mean age of 13.98 years, orthodontically treated by rapid maxillary expansion followed by corrective mechanics with extraction of four premolars or two maxillary premolars. Dental casts obtained from all patients at initial (T1), final (T2) and postretention stages (T3) were assessed by measurements of the Little irregularity index, intercanine, interpremolar and intermolar widths, maxillary arch length and perimeter. The results demonstrated that the Little irregularity index presented 9.40% of relapse for Group 1 and 13.57% for Group 2. There was no statistically significant difference between groups regarding the relapse in intercanine, interpremolar and intermolar widths, length and perimeter of the maxillary arch. However, Group 2 exhibited a greater amount of relapse in the maxillary anterior crowding. Thus, rapid maxillary expansion influenced negatively the maxillary incisors alignment stability.

PROPOSITION

The objective of this retrospective study was to evaluate the relapse of the maxillary anterior crowding in cases treated orthodontically without extractions, using the Little irregularity index, aiming to:

- » Compare the relapse of maxillary anterior

crowding between the Angle Class I and Class II malocclusions.

- » Correlate the Little irregularity index, the intercanine, interpremolar and intermolar widths, as well as the arch length at the initial and final stages and postretention period.

MATERIAL AND METHODS

Material

The sample used in this retrospective study consisted of 38 orthodontic records of patients treated at the Postgraduate Course in Orthodontics, University of São Paulo – Bauru Dental School, which showed, initially, Class I or Class II malocclusion and orthodontic treatment without extractions.

The criteria for sample selection also included the presence of all permanent teeth erupted at the beginning of orthodontic treatment (up to the first molars) and the absence of dental anomalies of shape and/or number. All patients were treated with fixed appliances and Edgewise mechanics and had complete orthodontic records, including dental casts at the initial, final and postretention stages.

The sample was divided into two groups by the classification of malocclusion according to Angle.

Thus, the groups were distributed as follows:

- » Group 1: Patients with Angle Class I — consisting of 19 patients who had maxillary anterior crowding at the beginning of orthodontic treatment.

- » Group 2: Patients with Angle Class II — comprising 19 patients with maxillary anterior crowding at the beginning of orthodontic treatment.

All patients used as retention, at the end of active orthodontic treatment, a removable Hawley retainer in the maxillary arch and a bonded lingual retainer from canine to canine in the mandibular arch. The Hawley was used for an average of one year, while the bonded lingual retainer for a mean period of 3 years.

Angle Class I group: Group 1

The Angle Class I group had 19 Caucasian patients (12 females and 7 males), with initial mean age of 13.06 years ($SD = 1.27$). The mean time of orthodontic treatment was 2.15 years ($SD = \pm 0.89$). After treatment, all patients had a satisfactory finishing. In this final phase, patients had a mean age of 15.19 years ($SD = \pm 1.24$). Patients belonging to Group 1 were evaluated after a mean postretention period of 8.60 years ($SD = \pm 1.83$).

Regarding the initial malocclusion, Group 1 had 19 patients with Class I malocclusion, with a maxillary anterior irregularity according to Little¹⁶ greater or equal to 3 mm.

Angle Class II group: Group 2

Group 2 comprised patients who had an initial Angle Class II malocclusion, with 19 Caucasians patients (14 female and 5 male) with a mean age of 12.54 years ($SD = \pm 1.37$) at the beginning of orthodontic therapy. The mean treatment time was 2.32 years ($SD = \pm 0.73$). After treatment, all patients, as well as patients belonging to Group 1, had a satisfactory finishing. In this phase, patients had a mean age of 14.93 years ($SD = \pm 1.50$) and were reassessed after a mean postretention period of 8.04 years ($SD = \pm 2.11$).

Regarding the initial malocclusion, Group 1 had 19 patients with Class I malocclusion, with a maxillary anterior irregularity according to Little¹⁶ greater or equal to 3 mm.

Methods

In the archives of the Department of Pediatric Dentistry, Orthodontics and Public Health of Bauru Dental School - University of São Paulo, Discipline of Orthodontics, all orthodontic records and dental casts of initial, final and postretention stages were examined, in order to select the sample following the above criteria. All these patients had been treated by

post-graduate students of specialization course (*Latu sensu*) and MSc/PhD (*Strictu sensu*) courses in Orthodontics at that institution. After the registration of all selected cases, those whose dental casts presented with artifacts of technique, absence of one or more follow-up stages (initial, final and postretention), or even badly damaged as to make it impossible their use were discarded.

The orthodontic records of the selected sample were used to obtain some relevant data to conduct this research. The personal information form was used to record the full patients names, gender and birth date. The clinical procedure records were examined as for beginning and end of treatment stages and completion of post-treatment controls. The time of retention removal was also noted. These data, together with the patient's date of birth, allowed accurate determination of the total treatment time, postretention time and patient ages in the studied phases.

When factors that might interfere with the sample standardization were noted, such as failures in the maintenance of records and models, inconsistencies in relation to the severity and type of malocclusion or inappropriate postretention evaluation period, the case was immediately excluded from the sample.

Dental casts' evaluation

Dental casts at the beginning of treatment (T1-initial), end of treatment (T2-final) and postretention (T3-postretention) were evaluated. The post-treatment dental casts were obtained at least 5 years after the end of treatment. All the measurements performed were obtained using a digital caliper (Mitutoyo Sul Americana Ltda., São Paulo, Brazil, model/code 500-143B), with a capacity of 150 mm, with precision of 0.01 mm.

The variables studied in the maxillary dental casts were:

Little Irregularity Index (modified) (LITTLE): The irregularity index proposed by Little¹⁶ was

ideally elaborated for the evaluation of the dental crowding in the mandibular anterior segment. However, due to its great reproducibility and precision, the same methodology to evaluate the dental displacement was used in the present study for the evaluation of the maxillary anterior crowding. Little index was calculated in the maxillary dental casts in the three studied phases (LITTLE1, LITTLE2 and LITTLE3). For this measurement, a digital caliper was used positioned parallel to the occlusal plane. The irregularity index was measured in this manner and characterized by the sum of the linear distance among the anatomic contact points of the maxillary anterior teeth (canines and incisors). This measure represents the distance in which the contact points should be moved to attain alignment. According to Little,¹⁶ even though the contact points may vary in the vertical direction, the correction of these discrepancies will not affect significantly the anterior length of the arch, this way, changes in the vertical direction were not considered (Fig 1).

Inter canine width (INTERC): Distance measured in millimeters, from cusp to cusp of the right and left maxillary canines. In cases where canines presented wear surfaces, the cusp was estimated.

Interpremolar width (INTERPB and INTERPB'): Distances measured in millimeters, between the mesial cavity of the right and left first maxillary premolars (B) and of the second maxillary premolars (B'), respectively.

Intermolar width (INTERM): Distance measured in millimeters, from mesiobuccal cusps of the right and left first maxillary molars. In cases where molars presented wear surfaces, the cusp was estimated.

Maxillary arch length (ALENGTH): Sum of the distances measured between the contact point of the maxillary central incisors and the mesial surface of the first molars of the right and left sides.

Error of the method

The intra-examiner error was evaluated by new measurements of the studied variables performed on the initial, final and postretention casts of 10 randomly selected patients belonging to both groups. The reassessed variables (LITTLE, INTERC, INTERPB, INTERPB', INTERM and ALENGTH) were also randomly selected. The first and second measurements were performed with a one month time difference. The formula proposed by Dahlberg⁶ ($Se^2 = \Sigma d^2 / 2n$) was used to estimate the order of magnitude of the casual errors, while the systematic errors were analyzed by paired t-tests, according to Houston.¹³

Statistical methods

Descriptive statistics was performed (mean, standard deviation and number) for Groups 1 (Class I) and 2 (Class II) for the measurements obtained by Little irregularity index, intercanine, interpremolar and intermolar widths and arch length, in the initial (T1), final (T2) and postretention (T3) phases. Descriptive statistic was also performed for the difference of the measures obtained from the dental casts between initial and final phases (T2-T1), characterizing the correction achieved with treatment,

and for the difference between the postretention and final phases (T3-T2), characterizing the changes during postretention period, and for the difference between postretention and initial phases (T3-T1), characterizing the changes during the whole observation period.

For compatibility evaluation between Groups 1 and 2 regarding gender distribution and in relation to the initial malocclusion severity, the Chi-square test was used. Aiming to verify compatibility between groups regarding the amount of initial crowding (LITTLE), initial age (Age T1), final age (Age T2) and age at postretention (Age T3), treatment time, retention time and postretention evaluation, independent t-test was used.

For intragroup comparison among the three evaluation times (Initial – T1; Final – T2; Postretention – T3), the dependent ANOVA test was used and, in case of a significant result, the Tukey test. The test was applied for the evaluation of the variables measured in dental casts from Groups 1 and 2 together, in the three evaluated periods.

For the intergroup comparison of the values obtained for variables evaluated in the dental casts of initial, final and postretention phases, as well as the changes of these variables during treatment (T2-T1), postretention (T3-T2) and total changes (T3-T1), the independent t-test was used.

Finally, to verify the presence of correlation between relapse of maxillary anterior crowding and relapse of the variables intercanine, interpremolar and intermolar widths and arch length, the Pearson's correlation test was used.

All tests were performed by STATISTICA for Windows software (Release 6.0 – StatSoft, Inc. 2001), adopting a significance level of 5%.

RESULTS

Table 1 shows the results of random and systematic errors, performed by the Dahlberg's formula⁶ and paired t-tests, respectively, applied

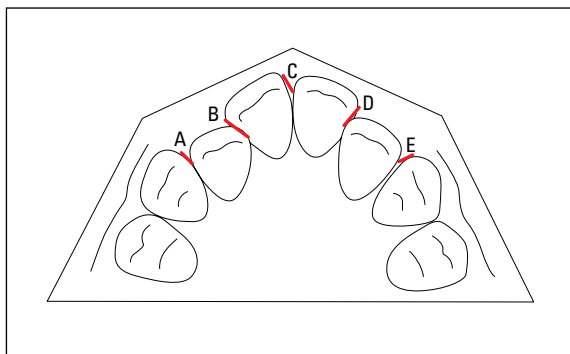


FIGURE 1 - Little irregularity index (modified) = A+B+C+D+E.

to the variables LITTLE, INTERC, INTERPB, INTERPB', INTERM and ALENGTH, and measured on dental casts within a one-month interval.

Group compatibility regarding gender distribution was evaluated by the Chi-square test (Table 2). There was no statistically significant difference between the groups regarding gender distribution.

The independent t-test was used to assess the compatibility of groups regarding the amount of initial maxillary anterior crowding (LITTLE1), initial age (Age T1), final age (Age T2), age at postretention stage (Age T3), treatment time (TREATTIME) and postretention time (POSTTREATTIME). There was no significant difference between groups on these variables (Table 3).

The results of the ANOVA for the variables measured on dental casts of Groups 1 and 2, respectively, in the three studied periods (T1, T2 and T3) can be verified in Tables 4 and 5. In the presence of a significant result, the Tukey test was performed. The results for Group 1 showed a significant reduction in maxillary anterior crowding and statistically significant dimensional increments between the initial (T1) and final phases (T2), except for the intercanine width (INTERC) (Table 4).

It was observed that these changes tended to be stable in the postretention period, except for the interpremolar width (INTERPB), and arch length (ALENGTH), which had a statistically significant decrease in postretention (T3) (Table 4). The results of the ANOVA for Group 2 show that Little's index had significant changes during treatment and during the postretention period (Table 5). However, there were no statistically significant changes for most of the other variables during these phases, except for the intercanine (INTERC) and intermolar widths (INTERM) which showed a significant decrease between the final (T2) and postretention stages (T3) (Table 5).

TABLE 1 - Results of t test and Dahlberg's formula,⁶ applied to the evaluated variables to estimate systematic and casual errors, respectively.

Variables	1st Measurement N=10		2nd Measurement N=10		Dahlberg	P
	Mean	SD	Mean	SD		
LITTLE1	7.02	3.08	7.05	3.13	0.05	0.397
LITTLE2	0.10	0.33	0.11	0.34	0.01	0.343
LITTLE3	1.47	0.81	1.49	0.80	0.02	0.422
INTERC1	34.21	3.06	33.25	4.58	0.25	0.322
INTERC2	34.38	2.28	34.44	2.25	0.07	0.135
INTERC3	34.60	2.33	34.57	2.34	0.05	0.527
INTERPB1	32.35	2.49	32.63	2.48	0.35	0.220
INTERPB2	36.03	2.09	35.82	2.23	0.26	0.246
INTERPB3	35.30	2.18	35.39	2.55	0.22	0.564
INTERPB'1	37.04	3.41	37.10	3.64	0.28	0.755
INTERPB'2	41.13	2.56	41.21	2.59	0.15	0.454
INTERPB'3	40.40	2.39	40.48	2.64	0.20	0.564
INTERM1	49.21	3.94	49.29	3.86	0.10	0.207
INTERM2	52.19	3.85	52.33	3.80	0.13	0.092
INTERM3	52.38	3.50	52.48	3.71	0.15	0.303
ALENGTH1	67.96	5.22	68.21	5.51	0.25	0.121
ALENGTH2	72.59	4.59	72.58	4.75	0.23	0.990
ALENGTH3	70.86	4.06	71.36	4.71	0.65	0.249

TABLE 2 - Results of the Chi-square test for evaluation of compatibility of the Groups 1 and 2 regarding gender distribution.

	Female	Male	Total
Group 1 - Class I	12	7	19
Group 2 - Class II	14	5	19
Total	26	12	38
X ² =0.49	df=1		p=0.485

TABLE 3 - Results of independent t test, applied to the variables initial Little index; initial, final and postretention age; treatment time and time of postretention evaluation for Groups 1 and 2, for evaluation of the intergroup compatibility.

Variables	Group 1 - Class I (N=19)		Group 2 - Class II (N=19)		P
	Mean	SD	Mean	SD	
LITTLE1	7.83	3.14	6.35	2.67	0.126
Age T1	13.06	1.27	12.54	1.37	0.233
Age T2	15.19	1.24	14.93	1.50	0.552
Age T3	21.67	2.52	20.62	2.41	0.201
TREATTIME	2.15	0.89	2.32	0.73	0.534
POSTTREATTIME	8.60	1.83	8.04	2.11	0.388

Tables 6, 7 and 8 show results of the independent t-test for intergroup comparison of the variables studied in the initial (T1), final (T2) and postretention stages (T3), respectively. In the initial phase, there was no statistically significant difference for all variables between Groups 1 and 2 (Table 6). In the final and postretention stages there were significant differences between Groups 1 and 2 for the amount of maxillary anterior crowding (LITTLE2 and LITTLE3, Tables 7 and 8, respectively).

Changes in variables measured in dental casts during treatment (T2-T1), during postretention period (T3-T2) and total changes (T3-T1) in both groups, were compared by t-tests (Tables 9, 10 and 11, respectively). In relation to changes that occurred during treatment (T2-T1), there were no significant differences between Groups 1 and 2 (Table 9). During the postretention

period (T3-T2), only the amount of maxillary anterior crowding presented statistically significant difference between groups (Table 10). In relation to the total changes (T3-T1), there were no statistically significant differences between Groups 1 and 2 (Table 11).

Table 12 shows the results of the Pearson correlation test. There was a negative correlation, statistically significant, between the amount of maxillary anterior crowding relapse and the amount of reduction in the intermolar width (Table 12).

DISCUSSION

Previous long-term studies that investigated anterior crowding relapse have most often evaluated the mandibular arch.^{3,4,11,17,18,20,30} There is a relative small number of studies that evaluated the maxillary arch and parameters that may be helpful in predicting its long-term

TABLE 4 - Results of ANOVA for the variables from dental casts, of Group 1 (N=19), in the three studied phases (T1, T2 and T3). In the presence of a significant result, the Tukey test was performed (different letters show significant difference between the measurements).

Variables	Initial T1	Final T2	Postretention T3	p
	Mean (SD)	Mean (SD)	Mean (SD)	
LITTLE	7.83 (3.14) ^A	0.34 (0.68) ^B	2.01 (1.87) ^B	0.000*
INTERC	33.79 (2.36) ^A	34.46 (1.48) ^A	34.29 (1.47) ^A	0.306
INTERPB	32.62 (1.91) ^A	35.91 (1.63) ^B	34.66 (1.54) ^C	0.000*
INTERPB'	37.91 (2.94) ^A	40.90 (2.19) ^B	40.02 (2.04) ^B	0.000*
INTERM	49.49 (3.16) ^A	51.53 (2.86) ^B	51.34 (2.69) ^B	0.000*
ALENGTH	68.33 (4.72) ^A	71.01 (3.45) ^B	69.48 (3.38) ^A	0.000*

*Statistically significant for $p < 0.05$.

TABLE 5 - Results of ANOVA for the variables from dental casts, of Group 2 (N=19), in the three studied phases (T1, T2 and T3). In the presence of a significant result, the Tukey test was performed (different letters show significant difference between the measurements).

Variables	Initial T1	Final T2	Postretention T3	p
	Mean (SD)	Mean (SD)	Mean (SD)	
LITTLE	6.35 (2.67) ^A	0.00 (0.00) ^B	0.80 (0.76) ^C	0.000*
INTERC	33.35 (2.71) ^A	34.42 (1.86) ^B	34.24 (2.06) ^{AB}	0.038*
INTERPB	32.08 (1.98) ^A	35.16 (1.76) ^B	34.69 (2.17) ^B	0.000*
INTERPB'	37.32 (2.51) ^A	39.93 (2.34) ^B	39.23 (2.07) ^B	0.000*
INTERM	49.71 (2.66) ^A	50.61 (2.04) ^A	50.72 (2.88) ^A	0.104
ALENGTH	68.59 (3.46) ^A	71.21 (3.75) ^B	70.06 (3.19) ^B	0.000*

*Statistically significant for $p < 0.05$.

stability,^{8,9,14,23,29} probably because maxillary anterior crowding relapse is less prevalent when compared to the mandibular one.^{27,31} Despite of that, the search for predictive factors that might

improve dental alignment stability is valid, since treatment deterioration in this arch segment may also result in esthetic and functional deficiencies. Due to its location in the arch,

TABLE 6 - Results of independent t test, applied to the studied variables, to verify the differences in the initial stage (T1), between the Groups 1 and 2.

Variables	Group 1 - Class I (N=19)		Group 2 - Class II (N=19)		P
	Mean	SD	Mean	SD	
LITTLE1	7.83	3.14	6.35	2.67	0.126
INTERC1	33.79	2.36	33.35	2.71	0.603
INTERPB1	32.62	1.91	32.08	1.98	0.401
INTERPB'1	37.91	2.94	37.32	2.51	0.514
INTERM1	49.49	3.16	49.71	2.66	0.820
ALENGTH1	68.33	4.72	68.59	3.46	0.849

TABLE 7 - Results of independent t test, applied to the studied variables, to verify the differences in the final stage (T2), between Groups 1 and 2.

Variables	Group 1 - Class I (N=19)		Group 2 - Class II (N=19)		P
	Mean	SD	Mean	SD	
LITTLE2	0.34	0.68	0.00	0.00	0.034*
INTERC2	34.46	1.48	34.42	1.86	0.943
INTERPB2	35.91	1.63	35.16	1.76	0.182
INTERPB'2	40.90	2.19	39.93	2.34	0.198
INTERM2	51.53	2.86	50.61	3.04	0.347
ALENGTH2	71.01	3.45	71.21	3.75	0.868

*Statistically significant for $p < 0.05$.

TABLE 8 - Results of independent t test, applied to the studied variables, to verify the differences in the postretention stage (T3), between Groups 1 and 2.

Variables	Group 1 - Class I (N=19)		Group 2 - Class II (N=19)		P
	Mean	SD	Mean	SD	
LITTLE3	2.01	1.87	0.80	0.76	0.012*
INTERC3	34.29	1.47	34.24	2.06	0.939
INTERPB3	34.66	1.54	34.69	2.17	0.958
INTERPB'3	40.02	2.04	39.23	2.07	0.246
INTERM3	51.34	2.69	50.72	2.88	0.498
ALENGTH3	69.48	3.38	70.06	3.19	0.591

*Statistically significant for $p < 0.05$.

TABLE 9 - Results of independent t test, applied to the studied variables, to verify the differences in the treatment period (T2-T1), between Groups 1 and 2.

Variables	Group 1 - Class I (N=19)		Group 2 - Class II (N=19)		P
	Mean	SD	Mean	SD	
LITTLE2-1	-7.48	3.24	-6.35	2.67	0.247
INTERC2-1	0.56	2.67	1.06	2.07	0.525
INTERPB2-1	3.29	1.78	3.08	1.88	0.723
INTERPB'2-1	2.98	2.27	2.60	2.69	0.641
INTERM2-1	2.03	2.13	0.90	2.78	0.169
ALENGTH2-1	2.68	3.18	2.61	3.01	0.951

TABLE 10 - Results of independent t test, applied to the studied variables, to verify the differences in the post-treatment period (T3-T2), between Groups 1 and 2.

Variables	Group 1 - Class I (N=19)		Group 2 - Class II (N=19)		P
	Mean	SD	Mean	SD	
LITTLE3-2	1.67	1.45	0.80	0.76	0.026*
INTERC3-2	-0.16	0.89	-0.17	0.77	0.984
INTERPB3-2	-1.25	1.10	-0.47	1.47	0.072
INTERPB'3-2	-0.85	0.97	-0.70	1.21	0.670
INTERM3-2	-0.18	0.90	0.10	0.99	0.348
ALENGTH3-2	-1.53	0.75	-1.15	1.39	0.289

*Statistically significant for $p < 0.05$.

TABLE 11 - Results of independent t test, applied to the studied variables, to verify the differences of changes in the whole period of observation (T3-T1), between Groups 1 and 2.

Variables	Group 1 - Class I (N=19)		Group 2 - Class II (N=19)		P
	Mean	SD	Mean	SD	
LITTLE3-1	-5.81	3.94	-5.55	2.34	0.804
INTERC3-1	0.50	2.03	0.89	2.34	0.588
INTERPB3-1	2.04	1.56	2.61	2.24	0.370
INTERPB'3-1	2.10	2.20	1.90	2.13	0.775
INTERM3-1	1.84	2.34	1.01	2.42	0.287
ALENGTH3-1	1.14	3.10	1.46	2.29	0.718

TABLE 12 - Results of the Pearson's correlation test.

Variables	r	P
LITTLE1 x LITTLE3	0.101	0.545
LITTLE1 x LITTLE3-2	0.104	0.533
LITTLE2-1 x LITTLE3-2	-0.021	0.899
LITTLE3-2 x INTERC3-2	0.128	0.441
LITTLE3-2 x INTERPB3-2	-0.296	0.071
LITTLE3-2 x INTERPB'3-2	-0.177	0.286
LITTLE3-2 x INTERM3-2	-0.342	0.035*
LITTLE3-2 x ALENGTH3-2	-0.301	0.065

*Statistically significant for $p < 0.05$.

maxillary crowding tends to become more visible and, consequently, promote more esthetic problems than mandibular incisor irregularity. However, depending on patient's smile height, it may also not occur.

Sample selection included dental cast evaluation. Group 1 comprised patients who exhibited Class I molar relationship and Group 2 consisted of patients presenting at least $\frac{3}{4}$ of a Class II molar relationship. Both groups were treated without extractions. Another sample selection criterion was that all patients had been treated with fixed Edgewise appliances, in both arches.

During sample selection, one of the concerns was to eliminate possible factors that might influence the results. One of the main objectives during this study development was to obtain compatible groups which would facilitate comparison and, consequently, would favor interpretation and reliability of the results. For this, the characteristics were homogenized in the beginning and end of the orthodontic treatment. The groups were compatible regarding to treatment protocol, the kind of orthodontic accessory used, sex distributions and initial malocclusion. Besides, groups

had other compatible characteristics, such as: Initial and final ages, treatment time, postretention evaluation time. Thus, the changes that occurred in the postretention period could be analyzed safely.

Regarding stability, there are considerable controversies in the literature about long-term post retention maxillary crowding relapse in different types of malocclusion (Class I and Class II subjects).^{25,31} Some studies reported that the greater the initial malocclusion severity, the greater the long-term relapse.^{10,18} Therefore, relapse of maxillary anterior crowding was evaluated in two groups that presented similar pretreatment incisors irregularity. The intergroup compatibility evaluation regarding pretreatment incisor irregularity was performed by t-test. No significant differences were observed between groups regarding initial irregularity (Table 3).

Intragroup comparison

The results for ANOVA and Tukey's test in Group 1 (Table 4) showed statistically significant changes in Little's irregularity index between initial and final or post-treatment phases. No statistically significant differences were noted between final and post-treatment phases. It may be inferred by interpreting these results, that orthodontic treatment resulted in significant maxillary crowding correction. During post-treatment period, there was no significant maxillary crowding relapse.

Inter canine width showed no significant changes during the three treatment stages (Table 4). These results could support the concept that stable results can be gained only when inter canine width is maintained.^{12,28} However, it is difficult to distinguish between inter canine width relapse and the normal decrease of this measure that occurs over the years in normal occlusion development, as others studies have reported.^{18,28}

Regarding changes in maxillary arch dimensions during treatment, significant transversal increases were noted (variables INTERPB, INTERPB' INTERM). Mean arch length increase was also significant. Only interfirstpremolar width decreased significantly during postretention, but not enough to reach initial values. The arch length width also showed a significant change during post-treatment, reaching a mean value close to the initial one.

Results for ANOVA and Tukey's test in Group 2 (Table 5) showed statistically significant differences in Little's irregularity index in the three stages evaluated. Thus, it was observed that the changes in variable LITTLE were not similar to Group 1. Significant reduction in maxillary crowding occurred during treatment. However, during post-treatment period, there was significant maxillary anterior irregularity relapse, that did not reach pretreatment mean value.

The variables INTERC, INTERPB, INTERPB' and ALENGTH showed statistically significant increases during treatment and did not exhibit a significant relapse when evaluating the final and postretention stages. The intermolar width showed no statistically significant changes in any of the studied phases.

Intergroup comparison

When comparing Groups 1 and 2 (Class I and Class II malocclusion subjects, respectively) in pretreatment, it was observed that none of the evaluated variables showed significant differences between groups (Table 6). Some studies that evaluated crowding relapse during long-term post-treatment mention that pretreatment irregularity is directly related to the amount of relapse,¹ although other authors have not observed this correlation.²⁰

Regarding the maxillary arch dimensions, it was noted that Groups 1 and 2 exhibited similar transverse dimensions (Table 6). McNamara²²

commented that, generally, transpalatal widths from 36 to 39 mm may accommodate an average size permanent dentition, without crowding or spacing.

As previously mentioned, the initial maxillary crowding severity, and other pretreatment variables were similar between the groups at T1, allowing a reliable comparative evaluation of the long-term post-treatment changes.

When comparing Groups 1 and 2 at post-treatment, the only variable that differed significantly between the groups was Little's irregularity index. There was more incisor irregularity in Class I subjects, indicating that Group 2 patients exhibited more quality in maxillary incisor alignment at T2 (Table 7). Although statistically significant, difference in irregularity between the groups was only 0.34 mm, which may not be considered clinically significant. Accordingly to Little,¹⁸ dental arch irregularity values between 0 and 1 mm consist in ideal alignments.

During postretention, the only variable that showed a significant intergroup difference was Little's irregularity index (LITTLE3), while other variables as INTERC3, INTERPB3, INTERPB'3, INTERM3 and ALENGTH3 showed no statistically significant differences (Table 8). These results suggested a similar behavior of the groups during postretention regarding dimensional changes.

Intergroup comparison of treatment changes revealed no significant difference between groups in the amount of maxillary crowding correction (LITTLE2-1, Table 9). This result was expected since there were no statistically significant differences between groups in the initial and final maxillary incisor irregularities.

During treatment, the amount of decrease in maxillary incisors irregularity was similar to previous studies that evaluated non-extraction treatment stability.^{7,32} However, some studies reported less reduction in incisor irregularity

during treatment because the sample exhibited less pretreatment incisor irregularity.⁸

The fact is that all these studies aimed at eliminating the incisors irregularity during treatment. Thus, variation in the amount of crowding correction is often due to variation in initial crowding severity.

The amount of maxillary incisors crowding relapse (LITTLE3-2) was statistically different between groups. Group 1 (Angle Class I subjects) exhibited a mean crowding relapse of 1.67 mm (SD = 1.45 mm). Group 2 (Angle Class II subjects) showed a mean crowding relapse of 0.80 mm (SD = 0.76 mm). Thus, there was greater treatment stability in Group 2 (Table 10).

This significant difference between the groups regarding incisors alignment stability may be due to orthodontic mechanics performed in patients of each group. In Class II subjects (Group 2), treated without extraction, there was, necessarily, distalization of maxillary molars. Therefore, more space could be gained for teeth alignment and this fact might have favored on stability. In Group 1 (Class I malocclusion), the molars remained stable in their initial positions during treatment. The crowding was corrected by dental protrusion and maxillary arch expansion, perhaps contributing to maxillary anterior crowding relapse.

Sadowsky et al²⁷, while evaluating the long-term stability of non-extraction cases, observed a similar amount of relapse (1.1 mm) five years postretention. However, Moussa, O'Reilly and Close²³ observed more favorable results 8-10 years postretention. Vaden et al³² found that 96% of maxillary crowding correction was maintained 15 years post-treatment. The amount of crowding increased from 1.5 mm (post-treatment) to 1.8 mm (postretention). Ferris et al⁹ also evaluated the relapse of maxillary anterior crowding in cases treated without extractions and observed an increase in maxillary incisors

irregularity of only 0.47 (SD = 1.19) during postretention (7.9 years). The greater maxillary incisors alignment stability of these studies may be due to the prolonged use of retention.^{3,23,27} In Sadowsky et al²⁷ study, the mean retention period was 8.4 years. Moussa, O'Reilly and Close²³ study adopted a mean retention period of 6.6 years in the mandibular arch (fixed retention) and 2 years for the maxillary arch (Hawley retainer). In the research conducted by Vaden et al,³² patients used Hawley retainers in mandibular and maxillary arches or Hawley retainer in the maxillary arch and bonded lingual retainer in the lower arch. The first long-term post-treatment evaluation was carried out only 6 years after treatment. In Ferris et al⁹ study, patients were submitted to a retention protocol that included the use of maxillary removable retainers for at least 3 years (one year of continuous usage) and a bonded lingual retainer or a Hawley retainer in mandibular arch during a mean period of 3 years. In the present study, all patients used a Hawley retainer in the maxillary arch during 1 year and a mandibular bonded lingual retainer for a mean period of 3 years.

Erdinc, Nanda and Isiksal⁸ evaluated long-term maxillary and mandibular incisors alignment stability in orthodontic patients treated with and without premolar extraction. An increase in maxillary and mandibular irregularities of 0.19 mm and 0.12 mm was observed in patients treated with and without extractions, respectively, 4 years and 11 months postretention. The extraction group had an initial crowding of 4.4 mm, whereas the non-extraction group showed a pretreatment crowding of 1.94 mm. The maxillary and mandibular removable retainers (Hawley) were removed at least two years before postretention assessment. The exceptional stability noted in this research may be related to the amount of initial irregularity and due to a short interval between retention removal and the long-term post-treatment evaluation.

Surbeck et al²⁹ observed a direct influence of pretreatment maxillary irregularity severity on amount of postretention relapse. The authors²⁹ suggested the adoption of individual retention protocols and that the orthodontist should explain to patients the probability of post-treatment relapse, accordingly to the initial irregularity severity.

However, analyzing the results of other authors and ours, a positive correlation between the amount of pretreatment crowding and the amount of long-term post-treatment relapse seems unlikely. For example, in the present study, Groups 1 and 2 presented 7.83 mm (SD = 3.14) and 6.35 mm (SD = 2.67) of pretreatment maxillary irregularity, respectively. A mean maxillary irregularity relapses of 1.67 mm (SD = 1.45 mm) for Group 1 and 0.80 mm (SD = 0.76 mm) for Group 2 was observed. The amount of irregularity relapse in the present study was greater than the crowding relapse observed by Ferris et al,⁹ Sadowsky et al²⁷ and Vaden et al.³² However, the sample in these studies showed greater maxillary pretreatment irregularity: 10.45 mm, 8.0 mm and 7.9 mm, respectively. Thus, even showing slightly greater amounts of initial crowding than the present study, maxillary incisors alignment in those studies was more stable during postretention (0.47 mm, 1.1 mm, 0.3 mm of long-term post-treatment relapse, respectively).

When evaluating overall changes (T3-T1), it was observed that maxillary anterior irregularity decreased 5.81 mm (SD = 3.94) and 5.55 mm (SD = 2.34) for Groups 1 and 2, respectively, and there were no statistically significant differences between groups (Table 11).

Correlation

Correlation tests were performed in the total sample to obtain the Pearson's correlation coefficients. Results showed a significant correlation between pretreatment and post-treatment

incisors irregularity (LITTLE1 and LITTLE3), between initial crowding (LITTLE1) and post-treatment crowding relapse (LITTLE3-2), and between crowding correction (LITTLE2-1) and postretention crowding relapse (LITTLE3-2). We also attempted to determine a possible correlation between maxillary crowding relapse (LITTLE3-2) and postretention changes in maxillary arch dimensions (INTERC3-2, INTERPB3-2, INTERPB'3-2, INTERM3-2 and ALENGTH3-2). Results are shown in Table 12.

Most results of the correlation tests were not significant. It was observed that pretreatment maxillary crowding severity did not influence the postretention crowding relapse, as described in previous studies.^{2,3,20} Surbeck et al,²⁹ however, reported a positive correlation between pretreatment crowding severity and the amount of maxillary anterior crowding relapse. Accordingly to the authors,²⁹ the odds of maxillary anterior relapse increase 2.3 times for every 0.2 mm displacement of incisors anatomic contact points relative to the dental arch, and 2.7 times for every 4° of incisor rotation. The authors also pointed out that incomplete alignment during active treatment is a significant risk factor for relapse.

Maxillary anterior crowding relapse (LITTLE3-2) showed a statistically significant ($p < 0.035$) correlation with the postretention changes in intermolar width (INTERM3-2). The observed correlation coefficient has a negative value. Interpreting this result, it seems that the greater the postretention intermolar width reduction, the greater the maxillary anterior crowding relapse. However, although this result has statistical significance, the correlation coefficient value shows a weak correlation ($r = -0.342$). Therefore, it may be inferred that the observed correlation has no clinical significance. The postretention decreases in the intermolar width may have occurred due to some pretreatment molar rotation that was corrected during treatment, and relapsed during long-term post-treatment evaluation.

CONCLUSIONS

According to the sample and methodology used and based on the presented and discussed results, it was concluded that:

» Class I malocclusion subjects treated non-extraction exhibited greater maxillary anterior crowding relapse than Class II subjects treated with the same protocol.

» The dimensional variables evaluated showed an increase in their mean values during orthodontic treatment and slight relapses during long-term post-treatment. The only measure that was correlated to the maxillary anterior crowding relapse was the postretention changes in intermolar width.

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Management of severe Class II malocclusion with sequential removable functional and orthodontic appliances: A case for MOrthRCSEd** examination

Larry Ching Fan Li***, Ricky Wing-Kit Wong****

Abstract

Introduction: Functional appliance is an effective way of treating skeletal Class II malocclusion in children and adolescents. A 12-month stepwise mandibular advancement protocol has been proved to enhance the condylar growth and improve the mandibular prognathism using Herbst appliance. **Objective:** The following case report documented a 11 year old Chinese girl with 11 mm overjet treated by a phase I 12-month growth modification therapy using Twin Block appliance with Hyrax palatal expander and high-pull headgear in a stepwise mandibular advancement protocol followed by a phase II preadjusted Edgewise appliance therapy. It is one of the cases submitted for the Membership of Orthodontics Examination of the Royal College of Surgeons of Edinburgh.

Keywords: Myofunctional therapy. Functional appliances. Angle Class II malocclusion.

Editor's abstract

For the treatment of Class II skeletal malocclusion due to mandibular retrusion, the use of functional orthopedics appliances is indicated with the purpose of stimulating mandibular growth. The present study deals with the presentation of a clinical case of a skeletal Class II malocclusion dealt with the Twin Block orthopedic appliance used together with a high-pull headgear followed by fixed orthodontic treatment. A Chinese patient, 10 years and 10 months of age, with convex facial profile, Class II, Division 1 malocclusion due to

mandibular retrusion, molar relationship of complete Class II, 11 mm overjet and moderate deep overbite, looked for orthodontic treatment complaining of crowding and protrusion of upper incisors. Through the analysis of cervical vertebrae, it was found that the patient was in stage CVS3, that is, near the peak of pubertal growth. Initially, the Twin Block appliance with an expansion screw was installed, with full time use, with initial mandibular advancement of 5 mm and vertical opening of 7 mm. Together with the Twin Block, a high-pull headgear with average force of 450 g/side was used

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12 to 14 h/day. After six months, the Twin Block appliance was adjusted to provide additional 5 mm of mandibular advancement. After 12 months, these devices were removed and fixed orthodontic appliance were used for alignment and leveling of the teeth and finishing the case. The total treatment time consisted of 26 months. The initial malocclusion was corrected obtaining normal molar relationship on both sides, plus a normal overjet and overbite. The facial profile was also improved, reflecting the improvement of the maxillomandibular relationship, due to a redirection of maxillary

growth, with its restriction in the anterior direction and considerable mandibular growth during the first phase of treatment (orthopedic). The authors concluded that this protocol for orthopedic treatment, with gradual mandibular advancement in 12 months, showed to be effective for the Class II malocclusion treatment associated with mandibular retrusion. However, evaluations associated with long-term studies involving a larger number of subjects should be conducted in order to scientifically prove the effectiveness of the proposed orthodontic/orthopedic treatment.

Questions for the authors

1) Currently, there are several appliances for orthopedic treatment of Class II malocclusion due to mandibular retrusion. Why was the Twin Block associated with the high-pull headgear chosen to treat this patient?

Removable functional appliance was used in this patient because her premolars were not fully erupted yet when treatment started.

Favourable compliance was also a deciding factor. The use of a high-pull headgear during the functional appliance stage was to restrain the downward maxillary growth and to minimize the backward and downward rotation of the mandible which would increase the overjet and jeopardize the treatment effects.

2) The 10-mm improvement in overjet occurred in 70% at the expense of skeletal structures and 30% due to dental changes, while improvement in the positioning of molars was 81% due to skeletal structures and 19% due to dental changes. In the authors' opinion, what was the reason for this significant skeletal correction with the treatment performed?

The skeletal correction is a combined result of maxillary growth restraint and enhanced mandibular growth.

A number of studies have shown that functional appliance (Herbst appliance) treatment with high-pull headgear in a stepwise advancement manner for 12 months produce greater skeletal improvement in Class II correction.

In this case, the lower incisor angulation increased very slightly during the Twin Block treatment and this contributed to the high percentage of skeletal changes (less dental changes) as well.

3) What factors should be considered for the choice between treating orthopedic/orthodontic in two phases in relation to that performed in only one stage?

The factors which need to be considered are:

» Cause of the Class II malocclusion (Dental or Skeletal); Prognathic maxilla, retrognathic mandible or a combination of both.

» Patient's facial profile.

» Age and skeletal maturity of the patient.

» Preference of the patients such as extraction of teeth, expected length of treatment, acceptance with the functional appliances and so on.

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Management of severe Class II malocclusion with sequential removable functional and orthodontic appliances: A case for MOrthRCSEd* examination

Larry Ching Fan Li**, Ricky Wing-Kit Wong***

Abstract

Introduction: Functional appliance is an effective way of treating skeletal Class II malocclusion in children and adolescents. A 12-month stepwise mandibular advancement protocol has been proved to enhance the condylar growth and improve the mandibular prognathism using Herbst appliance. **Objective:** The following case report documented a 11 year old Chinese girl with 11 mm overjet treated by a phase I 12-month growth modification therapy using Twin Block appliance with Hyrax palatal expander and high-pull headgear in a stepwise mandibular advancement protocol followed by a phase II preadjusted Edgewise appliance therapy. It is one of the cases submitted for the Membership of Orthodontics Examination of the Royal College of Surgeons of Edinburgh.

Keywords: Myofunctional therapy. Functional appliances. Angle Class II malocclusion.

INTRODUCTION

Based on the incisor relationship, Class II malocclusion is defined as the lower incisor edges lying posterior to the cingulum plateau of the upper incisors resulting in an increase in overjet.¹ The prevalence of having an overjet greater than 10 mm was reported to be around 0.2% of the population.²

Large overjet, especially in children and adolescents, is associated not only with an increased risk of traumatic injury to the upper anterior teeth but also psychological distress which results in loss of self-esteem and problems with social interaction. Among different malocclusions, Class II malocclusion was rated as the most unattractive

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by both orthodontists and laypersons.³ Albino⁴ as-
sets appearance is the most common reason given
for seeking treatments.

Class II malocclusion can usually be cor-
rected by either extracting two upper premo-
lars followed by retraction of the upper anterior
teeth (camouflage) or advancing the mandible
by growth modification or orthognathic surgery.
There are still controversies about how effec-
tive is growth modification for the correction of
large overjets. Fixed functional appliances such
as Herbst has been proven to effectively enhance
condylar growth and improve mandibular pro-
gnathism in both adolescents⁵ and adults⁶ using
a 12 month stepwise mandibular advancement
protocol.⁷ The following case report document-
ed a 11 year and 2 month old Chinese girl with
11 mm overjet treated by a phase I growth modi-
fication using Twin Block appliance with the 12
month stepwise protocol followed by a phase II
preadjusted Edgewise appliance therapy. It is one
of the cases submitted to the Membership of Or-
thodontics Examination of the Royal College of
Surgeons of Edinburgh (MOrthRCSEd).

CASE PRESENTATION

Clinical examination and diagnostic summary

A 10 year and 10 month old Chinese girl at-
tended our clinic complaining of crooked and
sticking out upper anterior teeth. Extraorally,
she had no apparent facial asymmetry. The lips
were incompetent at rest due to an increase in
overjet and also unfavorable muscle tone. The
upper lip length was 18 mm, which was consid-
ered shorter than the average. There was an ac-
ceptable amount of incisal and gingival display
on smiling and at rest, with the upper and lower
dental midlines coinciding with the midfacial
line. The nasolabial angle was acute, reflecting
the protrusive upper lip, which together with
the retruded mandible and chin, contributed
to her convex profile. The temporomandibular
joints were normal.

Intraorally, she presented a early permanent
dentition with a Class II Division 1, incisor re-
lationship and increased overjet of 11 mm. The over-
bite was increased at 4 mm (57%), complete and
traumatic. The molar and canine relationships were
full unit Class II on both sides. There was scissor-
bite between teeth #14 and #44. There was mild
crowding in the upper arch. The curve of Spee was
increased at 3 mm. She also had a reduced anterior
Bolton tooth size ratio of 71.3% (77.7% for normal
Class II Southern Chinese females⁸) due to rela-
tively smaller teeth in the lower anterior segment.
The oral hygiene needed to be improved (Fig 1).

Radiographically, the increased ANB (6°) and
Wits appraisal (+6 mm) confirmed that the pa-
tient had a Class II skeletal pattern.⁹ The normal
SNA and reduced SNB and SNPg indicated a
normal maxilla, receding mandible and chin. The
SN-mandibular plane angle and the lower facial
proportion were normal. The upper incisors were
proclined while the lower incisors were normally
angulated. The lower incisors were far behind the
A-Pogonion line and the lower lip was retrusive to
the Ricketts E plane by 2.1 mm. The cervical ver-
tebrae maturation (CVM) stage was CVS3, which
was around the peak of growth spurt¹⁰ (Fig 2).

Aims of treatment

1. Improve oral hygiene.
2. Enhance forward growth of the mandible
to improve facial profile and mandible/cranial
base relationship.
3. Reduce overjet and overbite and achieve
Class I incisor and buccal segment relationships.
4. Relieve crowding and align teeth.
5. Eliminate lip trap and improve lip compe-
tency.

Orthodontic treatment comprised a phase
I 12-month growth modification therapy using
Twin Block appliance with Hyrax palatal expand-
er and high-pull headgear in a stepwise mandib-
ular advancement protocol and a phase II fixed pre-
adjusted Edgewise appliance treatment.



FIGURE 1 - Pretreatment intraoral views.



FIGURE 2 - Pretreatment lateral cephalometric and panoramic radiographs.

Treatment progress

Phase I: Growth modification therapy

The patient was referred to a dental hygienist for oral hygiene instruction and scaling and prophylaxis. After achieving a satisfactory oral hygiene level, orthodontic treatment commenced. An acrylic Twin Block appliance was issued for full-time wear with an initial mandibular advancement of 5 mm and 7 mm vertical opening at

the premolar area. The appliance was cemented for the first week to ensure initial compliance. A high-pull headgear was issued one month later and was worn with 450 gram of force on each side for 12 to 14 hours per day. After 6 months, the appliance was activated by advancing the mandible another 5 mm to achieve an edge to edge incisor relationship. At this stage, the Hyrax palatal expander was also activated at a rate of 0.5 mm per

week for 12 weeks to achieve a palatal expansion of 6 mm (Fig 3). Maxillary canine to canine were bonded with 0.014-in nickel-titanium (NiTi) archwire with laceback between teeth #11 and #21 to align the teeth.

Phase II: Fixed appliance

The Twin Block appliance was removed after 12 months into treatment. The overjet was reduced to 1 mm. Crowding was relieved in the

upper arch due to distalizing effect of the dentition as well as the palatal expansion. An upper Twin Block retainer providing a positive incisal stop was issued to be worn full-time for 3 months (Fig 4). Both upper and lower arches were bonded using 0.022 x 0.028-in slot preadjusted Edgewise appliance with Roth's prescription and aligned with 0.014-in nickel-titanium wires. The archwires were subsequently changed to 0.017 x 0.025-in NiTi for further alignment

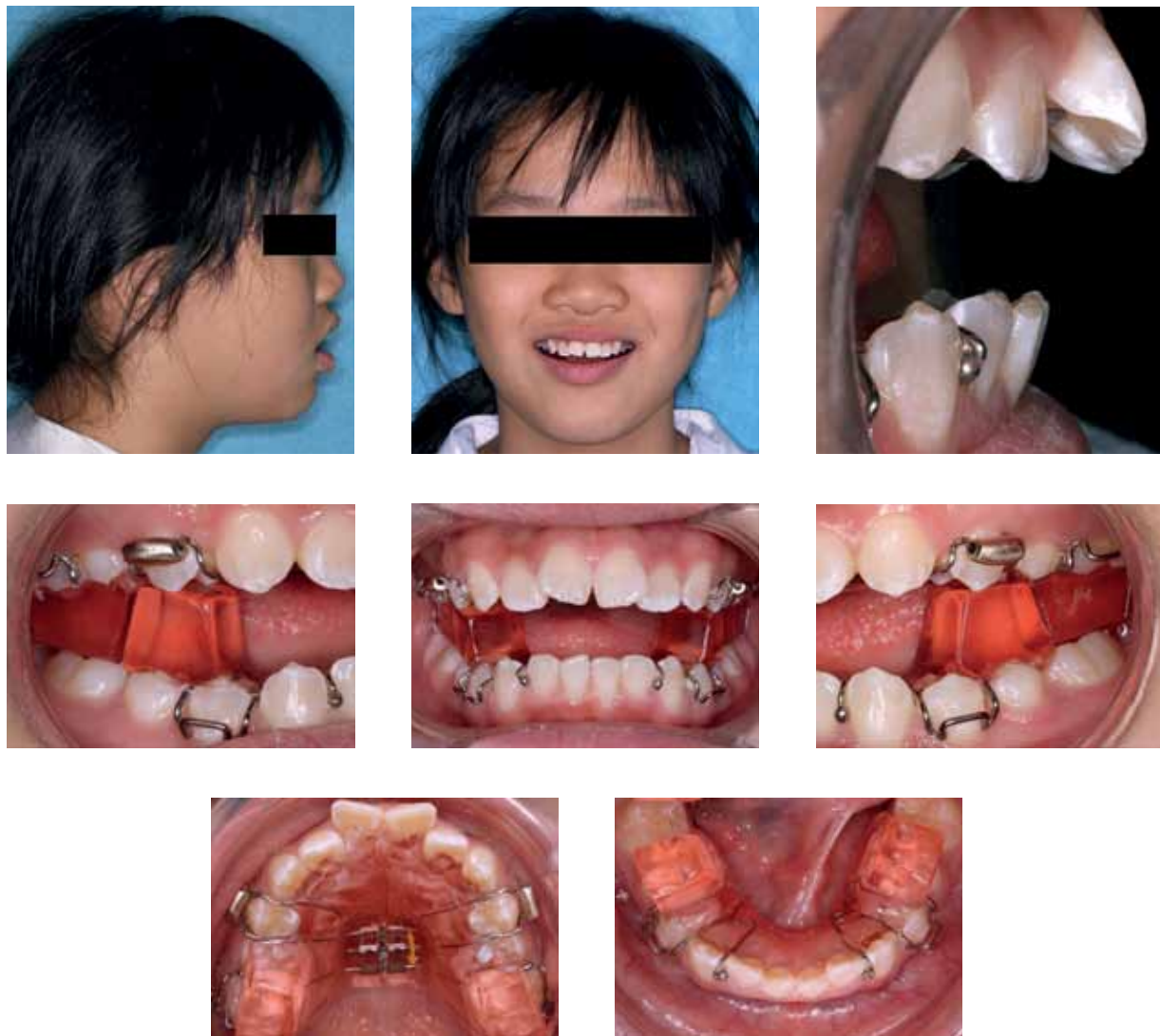


FIGURE 3 - Twin Block appliance bonded.

and for torque control. After three months, 0.017 x 0.025-in stainless steel archwire was placed on the upper arch while 0.019 x 0.025-in stainless steel archwire was used in the lower arch for arch coordination. Class II elastics were worn full time to maintain the buccal relationships and the overjet. The treatment was completed in 26 months. Fixed 0.018-in Twisflex fixed lingual retainers were delivered on both arches. Upper and lower Hawley's retainers were also issued as an additional protection measure against unnoticed debonding of the fixed lingual retainers.

Treatment changes

The total treatment time was 26 months. Overjet and overbite were reduced to 3 mm and 2.5 mm respectively. Super Class I buccal relationships were achieved on both sides. Canine guidance was present on the left and right sides during lateral excursions and incisal guidance was present on protrusion. There were no non-working side interferences during function. Protrusive movements were also normal. Good buccal interdigitation was achieved despite buccal overjet was slightly increased due to the tooth size discrepancy. A 97.8% reduction in PAR (Peer Assessment Rating) score was achieved with the

initial PAR score of 45 points reduced to 1 point post-treatment. This can be categorized as greatly improved (Figs 5, 6 and 7).

An appreciable amount of sagittal and vertical mandibular growth was observed during the treatment period. The facial profile, measured as facial convexity angle, improved 8°. Mandible/cranial base relationship improved to 3.6° and Wits appraisal value was at -2 mm indicating a Class I skeletal base.⁹ Vertically, the mandibular plane angle was unchanged when compared to pretreatment despite the lower facial height increased by 1.8%. From the superimposition, maxillary growth was restrained during headgear Twin Block treatment, and resumed to a forward and downward pattern during the phase II treatment (Table 1).

Maxillary cephalometric tracings superimposition (Fig 10) indicates that there has been retroclination of upper incisors. Eruption of upper molars was restrained during the headgear/Twin Block treatment, but they were extruded during phase II with fixed appliance treatment.

Mandibular cephalometric tracings superimposition (Fig 10) indicates that there has been very slight lower incisor proclination and maintenance of vertical position, and lower molars extruded and moved mesially during headgear/Twin Block treatment. This explained the development of mild crowding in the lower anterior region after headgear/Twin Block treatment. During the fixed appliance phase, there was continued extrusion of lower molars to level the curve of Spee. The lower incisors were retroclined as a result of rounding off the molar and premolar area. Upward and backward condylar growth was obvious during the overall treatment (Figs 8, 9 and 10).

Sagittal-Occlusion Analysis

From the Sagittal-Occlusion Analysis (SO-analysis)¹¹ immediately after 12 months of headgear/Twin Block treatment, the mandible/cranial base relationship (ss-pg) improved by 7 mm due to mandibular forward growth (pg/RLp' - pg/RLp) of 6.5 mm, and



FIGURE 4 - Twin Block retainer. Space developed distal to upper canines due to headgear effect of Twin Block appliance and palatal expansion.



FIGURE 5 - Post-treatment intraoral views.



FIGURE 6 - Comparison of pretreatment and post-treatment facial profile.



FIGURE 7 - Comparison of pretreatment and post-treatment smile.

a maxillary restraint (ss/RLp' - ss/RLp) of 0.5 mm. Maxillary growth restraint was not maintained after phase I, as sagittal maxillary growth caught up by 1 mm during phase II of treatment. For the mandible, pg-RLp continued to increase although at a much slower rate during phase II, and relapse was minimal according to the analysis.

From the SO-analysis during the headgear/Twin

Block phase I treatment, the upper incisors were retracted by 3 mm and the upper molars were distalized by 1.5 mm. The lower incisors were protracted by 0 mm and the lower molars by 3.5 mm. Overjet improvement of 10 mm was due to 70% skeletal and 30% dental changes, while molar improvement was due to 81% skeletal and 19% dental changes (Table 2).



FIGURE 8 - Post-Twin Block lateral cephalometric and panoramic radiographs.



FIGURE 9 - Post-treatment lateral cephalometric and panoramic radiographs.

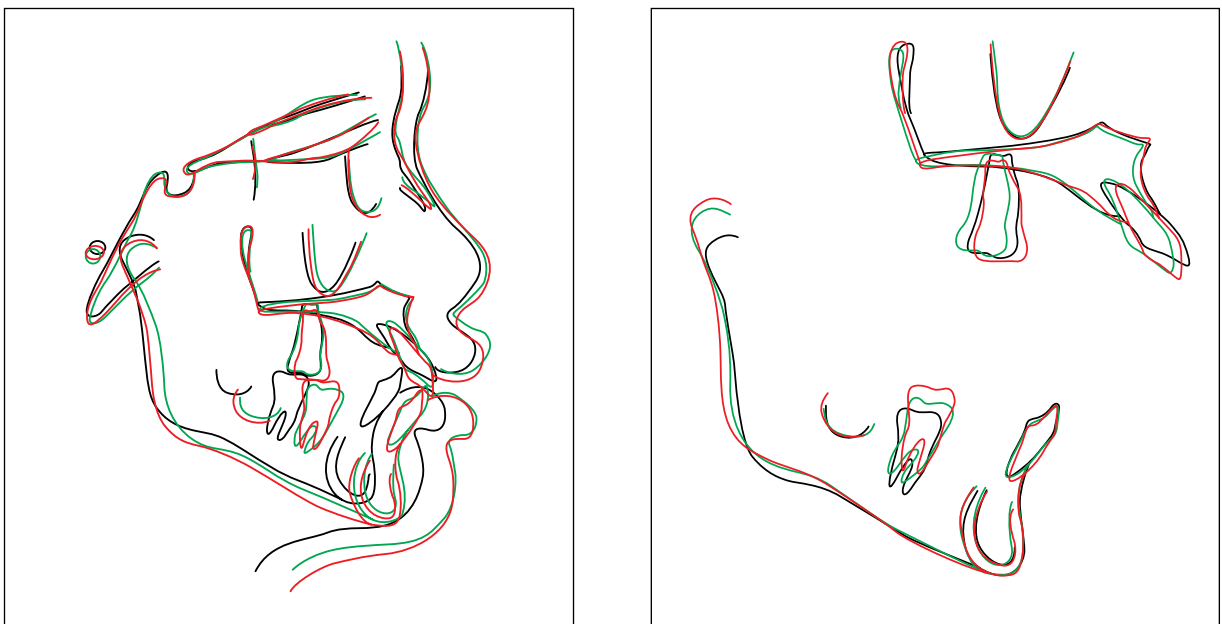


FIGURE 10 - Superimposition of pretreatment, midtreatment and post-treatment cephalometric tracings.

TABLE 1 - Cephalometric assessment.

Variable	Pretreatment	Post-treatment	Change
SNA	80.7°	80.9°	+0.2°
SNB	74.1° (1 sd)	77.3°	+3.2°
SN-Pg	74.7° (1 sd)	78°	+3.3°
ANB	6.6° (1 sd)	3.6°	-3°
Wits appraisal	+6 mm (2 sd)	-2 mm	-8 mm
Upper incisor to maxillary plane angle	129.7° (1 sd)	115.2°	-14.5°
Lower incisor to mandibular plane angle	98.2°	94.7°	-4.5°
Interincisal angle	102.4° (1 sd)	119.9°	+17.5°
SN to mandibular plane angle	38°	38.1°	+0.1°
SN to maxillary plane angle	8.4°	7.9°	-0.5°
Maxillomandibular plane angle	29.6°	30.2°	+0.6°
Upper anterior facial height	52.6 mm	53.2 mm	+0.6 mm
Lower anterior facial height	63.7 mm	69.5 mm (1 sd)	+5.8 mm
Facial height ratio	54.8%	56.6% (1 sd)	+1.8%
Lower incisor to Apo line	+1.6 mm (1 sd)	+4.9 mm	+3.3 mm
Lower lip to Ricketts E plane	1.9 mm	2.6 mm	+0.7 mm
Me-Go: S-N ratio	68:68	73:69	

Note that the norm values were based on a sample of 12 year old children.

Note: All values above have been adjusted to the SN-Frankfort Horizontal plane.

Sources of normal values for chinese:

Cooke MS and Wei SHY(1988) Eur J Orthod. 10(3):264-72

Cooke MS (1986) Ph. D Thesis. the University of Hong Kong. Cephalometric analyses based on natural head posture of children in Hong Kong

(1 sd) = One standard deviation.

(2 sd) = Two standard deviation.

DISCUSSION

Treatment rationale

In many respects the patient was an ideal candidate for functional appliance treatment. She presented with a mild to moderate Class II skeletal discrepancy, average vertical dimensions, mild crowding and proclined upper incisors, with the lower incisors presenting average inclination. The functional appliance was used to correct the skeletal discrepancy, and correct incisor and buccal segment relationships to Class I. As a result of the potential skeletal and dentoalveolar changes produced by the functional appliance, a more favorable soft tissue environment was created with elimination of the lip trap and the lower lip acting labially on the upper incisors.

Orthodontic camouflage by extraction of upper premolars could have been another treatment option but was not considered for a number of reasons. The patient and her mother were keen to avoid extractions due to concerns about removing healthy teeth. Extraction of upper premolar teeth might be able to retract the upper protrusive lip and improve facial convexity to certain extent, but would not improve mandibular retrognathism. Extraction approach also required careful anchorage management, which in her case, might involve headgear or bone anchorage, and thus carry other potential problems such as incompliance and patient discomfort.

Removable functional appliance was used in this patient because her premolars were not fully

erupted yet when the treatment started. Otherwise, Herbst appliance would be another option because we could minimize any potential compliance problem¹² and maximize treatment efficiency. The success of the treatment was largely dependent on the patient's compliance which was very well accomplished in this case. Mandibular advancement every six months in a stepwise manner has been proved more effective in stimulating condylar growth¹³ and improving mandibular prognathism.¹⁴ The use of high-pull headgear during the functional appliance stage helped restraining the maxillary growth and also prevented clockwise rotation of the maxilla which might cause backward and downward rotation of the mandible thus jeopardizing the treatment effects.¹⁵

Lower incisor proclination is one of the major side effects of functional appliances. In this case, the proclination of the lower incisors was minimized to only 0.6°. This common side effect in using functional appliance was avoided by trimming away the acrylic lingual to the lower anterior teeth. The fact that patient had smaller lower incisors and also the pressure from the lower lip might also have helped maintaining the angulations of the lower incisors.

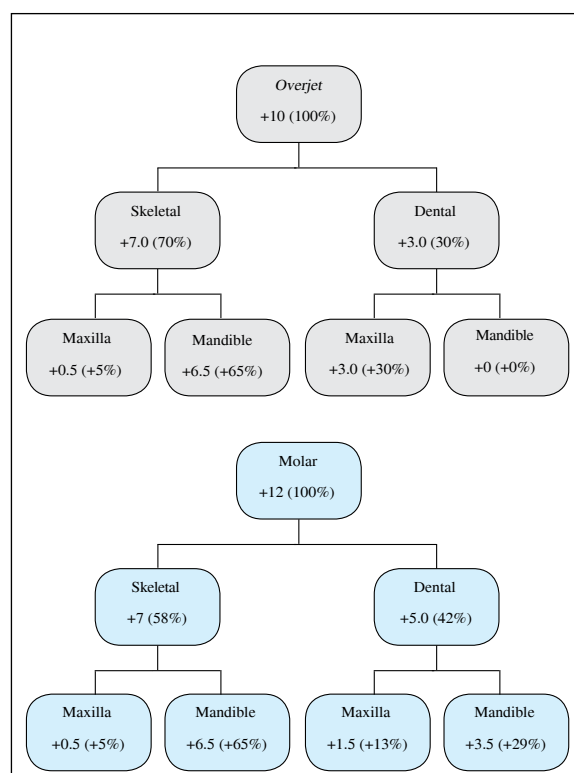
Two phase vs. one phase treatment

The total treatment time was 26 months including 12 months of growth modification. The main aim of the two phase orthodontic treatment was to enhance the patient's potential for favourable mandibular growth and improve her skeletal and soft tissue profile by growth modification. It was also planned to avoid over-retraction of her upper incisors with respect to the incisor angulations, future nasal growth and her existing smile line. The decision to start treatment with a first phase of functional appliance was proved to be appropriate.

The patient had her menarche in the sixth month during the Twin Block phase treatment, indicating that she was around the peak of her pubertal growth spurt,¹⁶ which was corresponding to her CVM stage.¹⁷ The treatment effect by the functional appliance could be maximized during this period.¹⁸

The lip competency improved although was not fully corrected due to unfavourable muscle tone. There was increased buccal overjet as a result of tooth size discrepancy between upper and lower arches. It was decided not to change the size and shape of the teeth by stripping or building-up with resin because of esthetic concerns. There was mild generalized gingival swelling at the interdental papilla area, despite fair oral hygiene had been maintained by the patient during treatment. The gingival swelling resolved greatly one week after debonding.

FIGURE 11 - Sagittal Occlusion Analysis.



Source of analysis: Pancherz,¹¹ 1982.

Long term prognosis

The mandibular intercanine width has been maintained at its original while the upper was expanded during the functional appliance phase. The prognosis for stability is good provided the patient's growth pattern is favourable and the mandible will not rotate downward and backward. Good buccal interdigitation and incisal contact also helped to stabilize the occlusal stability, as well as the fixed and removable retainers.

CONCLUSION

A number of researches have shown that a 12-month stepwise mandibular advancement protocol using headgear/Herbst appliance could enhance the condylar growth and improve the mandibular prognathism. This case report documented a successful treatment of a skeletal Class II using removable headgear/Twin Block appliance with the 12-month stepwise advancement protocol. The long-term clinical effects of such treatment protocol demand a case-controlled study with more samples and longer follow up period.

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A method to re-treat the relapse of dental misalignment

David Normando*, Leopoldino Capelozza Filho**

Abstract

The clinician should expect some loss of the dental alignment obtained during orthodontic therapy in the long term in cases in which the orthodontic retainer has been removed by the orthodontist or lost by the patient. In this situation, patients are often reluctant to wear braces again to re-treat anterior misalignment. This report describes the successful use of a simple and effective technique to correct mild changes in the incisor alignment after orthodontic treatment. An innovative and low cost procedure effectively solved the relapse of anterior misalignment in 1-2 months. The force used to realign the teeth is obtained through the use of a clear elastomeric thread tied to multistranded upper and lower retainers.

Keywords: Tooth movement. Orthodontic appliances. Incisor. Relapse.

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INTRODUCTION

Follow-up studies of treated cases have shown that although ideal occlusion and dental alignment have been achieved, there is a tendency for post-treatment relapse toward the original malocclusion.¹⁻⁴ Furthermore, patient's satisfaction is moderately associated with the stability of the orthodontic treatment⁵ while the use of retainers is one important factor related to treatment stability.⁴ Therefore, preserving dental alignment can contribute to a higher level of satisfaction in patients who have undergone orthodontic treatment.

The most effective way to re-treat mandibular anterior crowding or spacing after retention requires the use of brackets and archwires. However, patients are often reluctant to wear braces again for the purpose of aligning the affected teeth. Several alternatives have been proposed for tooth realignment, which may involve the use of an active removable appliance,⁶⁻¹⁰ retention with lingual spurs¹¹ or the use of nickel-titanium archwires as retention devices.¹² An innovative technique that involves an already installed retainer and a clear elastomeric solid thread is presented in this paper.

TECHNIQUE PRESENTATION

The use of fixed lower retainers is a routine in the orthodontic clinic¹⁴ and its efficiency has been widely reported in the orthodontic literature.^{4,13} However, the use of fixed upper retainers does not seem as popular among orthodontists. Thus, orthodontists routinely make use of a removable Hawley plate to retain the alignment of the upper dental arch, while for the lower arch bonded 3X3 retainer seems to be the first option.^{14,15} This choice seems to be based on the fact that relapse seems less frequent in the upper arch compared to the lower;^{1,4} it is also difficult to maintain the stability of the retainer bonded to the upper teeth because of the vertical overbite and of

the fracture risks due to incisal contact during mastication. Although misalignment is more frequent in the lower arch, it seems reasonable to believe that the instability of the upper arch causes more dissatisfaction for the patient, specially in cases where there is more esthetical exposure during smiling. Moreover, the effective bonding of an upper retainer requires additional care during the placement of the wire, which must be below the proximal contact points. However, a previous study¹⁶ has demonstrated excellent long-term success rates for upper and lower fixed retainers.

The technique presented in this paper requires the use of fixed retainers in both arches. It also seems important the use of multi-stranded wires, co-axial type, made of stainless steel with 0.021-in in diameter due to the excellent stability¹⁵ and surface roughness, which allows the wire to hold the elastomeric solid thread that will generate the necessary force to move the teeth. The direction of this force will be defined by the placement of the elastomeric thread in relation to the fixed retainer. This thread should be changed every two weeks. Thus, it is possible to correct labial displacements (Fig 1), tooth rotation (Fig 2) and spacing (Fig 3) in the upper and/or lower dental arches. However, it should be noted that in most cases of incisor labial displacement, it is necessary to create more space, which can be done by interproximal stripping (Fig 1).

CASE REPORTS

Three clinical cases are used to illustrate the technique presented in this paper. They are representative cases of dental misalignment after fracture or loss of a bonded retainer.

The first clinical case is a labial displacement relapse (Fig 1), the second case involves a lower incisor rotation relapse (Fig 2) and the third case is a retreatment of space opening (Fig 3). The method for tying the elastomeric thread on the retainer is shown and described in Figure 4.

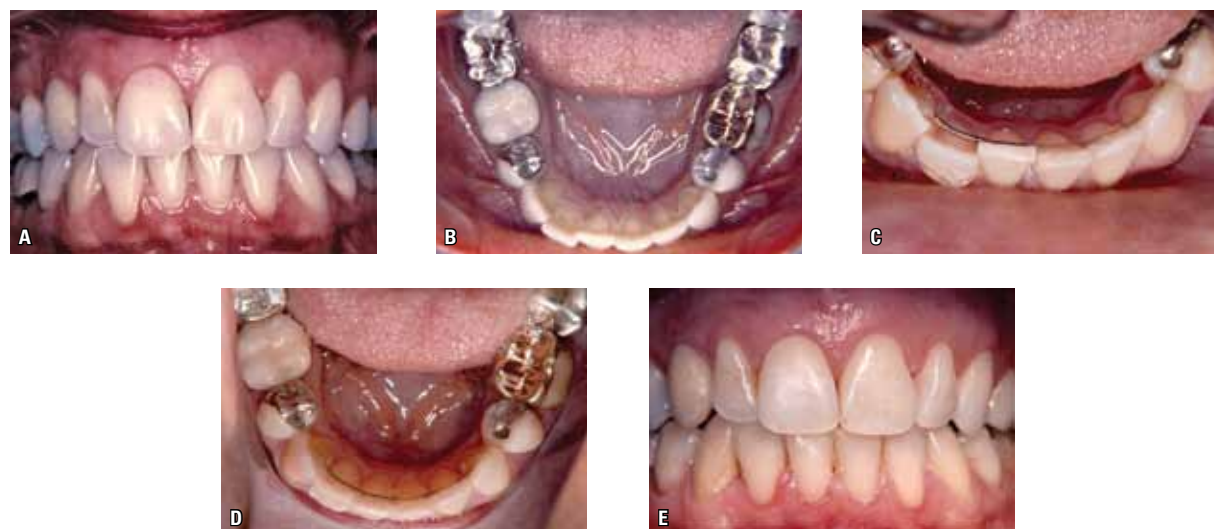


FIGURE 1 - Adult patient, 20 years after the orthodontic treatment, reported a mild labial displacement of tooth 42 (A) causing premature contact in MHI with tooth 12 (B) and consequent wear of its incisal edge. A lingually bonded lower retainer made of stainless steel co-axial multi-stranded wire, 0.0215-in in diameter (Penta-one Masel Orthodontics, Carlsbad, CA) was bonded to all lower anterior teeth except tooth 42. The 0.020-in elastomeric solid thread (Masel Orthodontics, Carlsbad, CA) was tied to tooth 42, which generated a force to move this tooth lingually (C). A slight stripping was necessary in the adjacent teeth in order to provide some space. The tooth was repositioned after 45 days. The solid thread was changed every two weeks (D, E).



FIGURE 2 - Lower right incisor rotation after bonded retainer failure (A). The solid thread was stretched and bonded with composite just on the distal surface (B). After 10 days, a significant improvement was observed and a new thread was inserted (C). After 20 days the case was finished and the tooth was rebonded to the lower retainer (D).



FIGURE 3 - Reopening space at the mesial of the upper lateral incisors after maxillary retainer bonding fracture (A). The retainer was still bonded to the upper canines and upper central incisors. A knot was made at the end of the solid thread (B) and this knot was bonded with composite to the labial surface of the upper left lateral incisor. The elastomeric thread was pulled and bonded to the upper right lateral incisor. The space was closed in just 10 days and the upper lateral incisors were rebonded to the upper retainer.

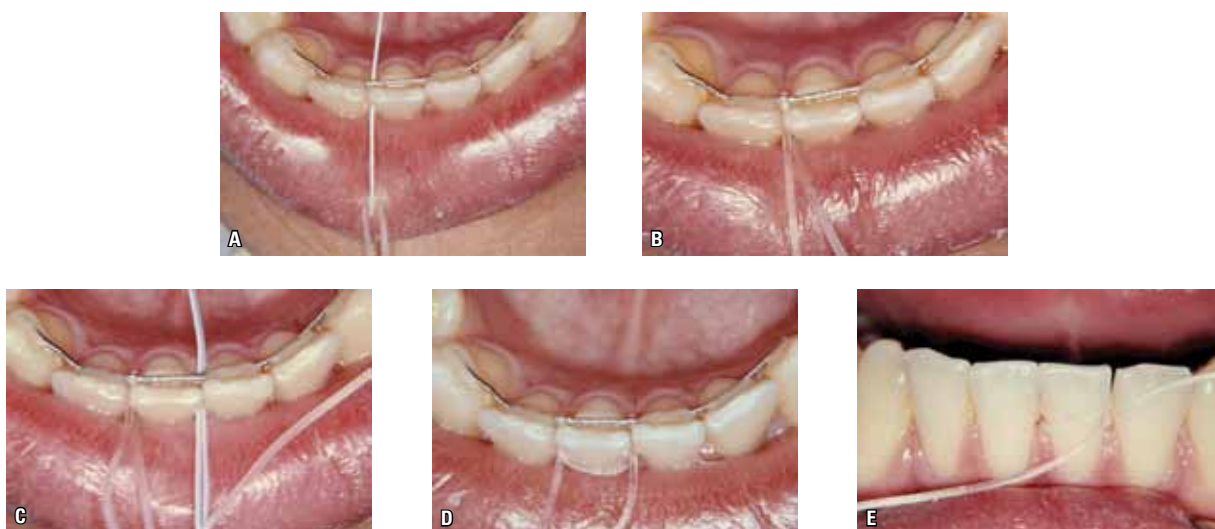


FIGURE 4 - Method used for tying the elastomeric thread when the goal is to produce lingual movement. With the aid of a floss threader, the solid thread is inserted under the retainer and the contact point of the tooth to be moved (A) in a buccolingual direction. The thread returns above the retainer (B). This procedure is repeated on the other proximal contact (C and D). Then, the thread is tied on the tooth labial surface (E). The knot can be bonded with a small amount of composite in order to facilitate its retention and to provide comfort to the patient (Video available at www.youtube.com/watch?v=sxKR3_TNlqc).

DISCUSSION

Treatment stability has been the main goal of orthodontics, although it is well known that treatment outcomes are not stable at all since a multiplicity of factors can interfere in the post-treatment occlusal balance leading to undesirable changes. Despite numerous published studies, a systematic review¹⁷ reports that there is insufficient research data on which to base our clinical practice choices on retention.

The risk of relapse in the anterior segment compared to the posterior⁴ is the clinical indication for a fixed lower anterior retainer. Multistranded wires has been proposed for the construction of fixed retainers based on their ability to allow for the physiologic movement of the teeth, whereas their surface offers increased mechanical retention for the adhesive.^{18,19} Despite multistranded retainers are efficient in preventing relapse of the mandibular anterior teeth,²⁰ post-treatment changes in the mandibular anterior teeth are expected when bonding failure occurs.¹⁻⁴

Longitudinal studies of orthodontically treated cases have demonstrated a tendency for relapse after treatment¹⁻⁴, even in well finished cases. These changes may occur suddenly in cases of loss or fracture of retainers. Even though the most effective manner for orthodontic retreatment of crowding or diastemas require the use of brackets and wires for leveling, the advantage of using a simpler, faster and cheaper procedure would by itself justify the adoption of this method. The technique described in this paper apart from being effective

seems to be better accepted by the patient because of the little time spent in retreatments and the low impact on esthetics. However, it requires the orthodontist to use fixed retainers for both dental arches. This approach is able to correct several minor changes postretention, such as buccal inclinations of the incisors (Fig 1), anterior rotations (Fig 2) and interincisal diastema (Fig 3) of anterior teeth.

Even though it is efficient for the correction of minor alterations, typical of misalignments in the anterior region of dental arch, it should be emphasized that major changes appear to be handled more efficiently with fixed appliances. In this case, the professional will have to surpass the usual patient resistance, who, generally, fights against using brackets and orthodontic wires or search for other alternative ways to perform re-treatment. Nevertheless, the disadvantage of installing fixed appliances once again for the correction of minor movements seems to perfectly be replaced by the method described in this paper.

CONCLUSION

The technique presented in this paper seems to be effective to correct mild changes in the anterior teeth alignment that can occur after orthodontic treatment because of the failure of bonded retainer. This simple procedure can be helpful only if the orthodontist has used upper and lower fixed retainers. Prospective studies involving larger samples must be conducted in order to scientifically investigate the rate of success for this clinical procedure.

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Electromyographic analysis of the orbicularis oris muscle in youngsters with Class II, Division 1 and normal occlusion

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Abstract

Aim: The purpose of this study was to make an electromyographic comparison of the action potentials of the upper and lower segments of the orbicularis oris muscle, bilaterally, in youngsters with Class II, Division 1 malocclusion and youngsters with normal occlusion in order to verify whether or not there is a difference between the two groups with regard to the electromyographic activity that occurs. **Methods:** The sample consisted of 50 girls, in the age-range from 8 to 10 years, with no previous orthodontic treatment, divided into two groups: 25 with Class II, Division 1 malocclusion and 25 with normal occlusion. Electromyographic signals of the orbicularis oris muscle were acquired using Ag/AgCl surface electrodes. Muscle activity was recorded in the resting position, in the isometric contraction and in the isotonic contraction and the Root Mean Square (RMS) values of each movement were determined. The data collected were submitted to statistical analyses of variance and Tukey test ($\alpha=0.05$). **Results:** The results showed that there was a difference in electromyographic activity between the young girls with Class II, Division 1 malocclusion and those with normal occlusion. Muscle activity was higher in the girls with malocclusion than in those with normal occlusion. **Conclusion:** This suggests lower competence of the orbicularis oris muscle in the girls with Class II, Division 1 malocclusion.

Keywords: Electromyography. Orthodontics. Class II Division 1. Normal occlusion. Orbicularis oris muscle.

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INTRODUCTION

Electromyographic analysis of the masticatory muscles constitutes an important complementary instrument in orthodontic diagnosis, as a careful evaluation of muscle activity before and during treatment guides the professional in selecting suitable therapy, as well as in the choice of more individualized retainers, minimizing relapses.²²

Perioral musculature and lip position are determinant factors in the position of the teeth and shape of the dental arch because of their moderate yet continuous activities. The forces resulting from the resting position of the lips help to define and maintain the occlusion. Patients with lip incompetence are unable to achieve habitual lip sealing without effort, a condition that favors dental protrusion by the reduction of lip pressure that acts on them, generating facial imbalance. The absence of contact between the lips causes a muscle imbalance that may affect various functions, such as breathing, swallowing and speech, besides the growth and harmonious development of the face.^{4,6,7,9,10,11,29}

There are three swallowing patterns: Normal, with accentuated contraction of the masseter muscle and limited activity of the labial and chin musculature; the visceral type, with little or no activity of the masseter, considerable contraction of the chin muscle and smooth activity of the lower segment of the orbicular muscle of the mouth; and the third, with marked activity of the lower segment of the orbicular and chin muscles, considerable contraction of the upper segment of the orbicular muscle of the mouth and minimum activity of the masseter. Both segments of the orbicular muscle of the mouth function as separate and independent entities.¹⁴

The behavioral pattern of the upper and lower segments of the orbicular muscle of the mouth evaluated in youngsters presenting normal occlusion shows the absence of significant electromyographic activity in this muscle during mastication and deglutition, as well as in the resting state. The lateral and medial regions, upper and lower segments may

function as independent organs between them, in spite of constituting one and the same muscle.^{5,18,30}

The synergic patterns of muscle behavior differ with regard to the anomalies of occlusion and are correlated to the existence or lack of efficiency of the masticatory mechanism.^{12,16,17}

Electromyographic studies of the masseter, orbicularis oris, mentalis and anterior portion of the temporal muscles, evaluated during normal deglutition and in atypical deglutition, have revealed that patients with normal deglutition presented accentuated contraction of the masseter muscle, little activity of the perioral muscles and absence of temporal muscle activity, whereas patients with atypical deglutition presented greater activity of the perioral muscles.^{22,26}

Electromyographic analysis of the orbicularis oris, temporal, masseter, pterygoid, mentalis and supra-hyoid muscles, during the movements of mastication, deglutition, rest, lip sealing, elevation, lowering and lateral movement of the mandible in youngsters with Class II, Division 1, when compared with a similar group of youngsters with normal occlusion, showed that all the youngsters with Class II, Division 1 presented alterations in the musculature intimately connected to the temporomandibular joint, and that orthodontic treatment could alter the action potential of some of these muscles.^{13,18} In mastication and deglutition, youngsters with malocclusion presented a tendency towards less electromyographic activity in all the muscles.¹ Lips considered incompetent before treatment became competent in approximately 25% of the evaluated cases.¹⁹ Youngsters with clinically normal occlusion presented more competent lips than those with Class II, Division 1.^{24,25,27}

The relationship between electromyographic activity of the upper and lower segments of the orbicularis oris muscle and predominantly nasal or mouth breathing indicated that greater activity of the muscle occurred in youngsters with predominantly mouth breathing than in those with predominantly nasal breathing.²³

Electromyographic activity of the buccinator, mentalis, orbicularis oris, temporal, masseter and mandibular depressor muscles during the movements of deglutition, light contact of the teeth, forced occlusion, suction, rest and various mandibular movements did not differ among children with deciduous dentition and adults with normal occlusion.²⁸ In patients presenting finger sucking habits, a predominance of activity of the orbicularis oris or mentalis muscle occurs, and during suction minimal contraction of the temporal muscle. In the presence of sucking habits, the abnormal muscular activity patterns become established and it is not enough to correct the habit if the muscular pattern persists.²

Since the shape of the dental arches and orofacial musculature activity interact reciprocally, the present study made an electromyographic evaluation of the action potentials of the orbicularis oris muscle in its upper and lower segments, in youngsters with Class II, Division 1 and in youngsters with clinically normal occlusion to verify whether or not there were differences in the electrical activity of this muscle between these groups.

MATERIAL AND METHODS

This research study was previously submitted to the Research Ethics Committee for evaluation and approval under number 147/2002 and was found to be in accordance with the Guidelines and Regulatory Rules of the National Council of Health, Resolution No. 196-1996.

The sample consisted of 50 young white girls, age-range between 8 and 10 years, who had never been submitted to orthodontic treatment before and were distributed into two groups: 25 with dental Class II, Division 1 and 25 with normal occlusion. The youngsters underwent clinical exam in which the relationship of the two permanent maxillary and mandibular first molars, incisal relationship in the vertical and horizontal

planes (overjet and overbite) and the relationship of the permanent and/or deciduous canines were observed. Each youngster was also asked to have complementary exams performed, which consisted of lateral cephalometric radiographs, panoramic radiographs, plaster casts as well as intra and extraoral photographs.

A chart especially designed for this research was used to note the personal data and occlusal characteristics of each selected youngster. During the clinical exam the following characteristics were observed in youngsters with Class II, Division 1:

1) Maxillary permanent first molars and deciduous canines mesially positioned in relation to the mandibular permanent first molars and deciduous canines, respectively.

2) Overjet larger than 3 mm.

Cephalometrically, the youngsters presented a vertical facial growth pattern with mean values of SN.GoGn angle of 35° and FMA angle of 27°, mean SNA angle of 80°, mean SNB angle of 75°, and mean ANB angle of 5°.

The following characteristics were considered to classify the youngsters with normal occlusion:

1) First permanent molars in key occlusion, that is, the mesio-buccal cusp of the maxillary permanent first molar occluding in the buccal sulcus of the mandibular permanent first molar; permanent and/or primary canines in Class I, that is to say, the tip of the buccal cusp of the maxillary canine occluding in the buccal embrasure between the mandibular canine and the mandibular deciduous first molar and/or mandibular first premolar.

2) Overjet and overbite of approximately 2.5 mm; absence of malpositioned teeth and absence of tooth crowding.

Cephalometrically, the subjects presented a vertical facial growth pattern with mean values of SN.GoGn angle of 35° and FMA angle of 27°, mean SNA angle of 81°, mean SNB angle of 79°, and mean ANB angle of 3°.

Electromyographic analysis

Electromyography is defined as the collection of information about muscle electrical activity by means of electrodes connected to equipment for signal amplification and recording.^{8,15,20,21} One of the forms of manipulating the signal occurs by determining the root mean square (Root Mean Square, RMS), representing the best method, since it considers the physiological alterations in the electromyographic signal, reflecting the number, frequency and the manners of action potentials of the active motor units, allowing an analysis of the electromyographic signal amplitude.³

For the electromyographic recording, the Signal Conditioner Myosystem-I® (Data Hominis Tecnologia Ltda, Brazil) was used, consisting of 12 channels with 12 bit dynamic range resolution, Butterworth type filter, low pass 500 Hz and high pass 20 Hz; 100 times gain, analog-to-digital converter board (A/D) with a capacity of 2000 Hz to 4000 Hz, 12 bits, Myosystem-I®, version 2.12 software, for simultaneous presentation of the signals from 12 channels and signal treatment (value of RMS, mean, minimum, maximum and standard deviation), with sampling frequency of 2000 Hz.

To capture the action potentials of the orbicularis oris muscle, passive surface Ag/AgCl electrodes from Data Hominis Tecnologia Ltda. were used. A reference electrode (ground) consisting of a stainless steel metal plate was also used with the purpose of reducing noise during electromyographic signal acquisition.

The volunteers remained seated on chairs, in the most comfortable manner possible with the back supported by the chair-back and the head positioned with the Frankfurt plane parallel to the ground, eyes open, feet supported on the ground and arms supported on the lower limbs. A pair of surface electrodes, previously coated with electric conductor gel, was fixed to the mid portion of the upper lip with plaster tape, 2 mm above its free edge, 1 cm distant

from one another and the same procedure was adopted for the lower lip with the electrodes fixed 2 mm below its margin. The reference electrode (ground), connected to the surface electrode and previously coated with electric conductor gel was also fixed to the right wrist of each of the volunteers, with the aid of velcro tape. Before beginning with electromyographic signal collection, all the volunteers were informed about the characteristics of the equipment and given instructions about the movements they should make, in addition to previous training.

The electromyographic recordings began with evaluation of the resting position and, after this, during isometric contraction and isotonic contraction. For each of the above-mentioned situations, a collection time of 10 seconds was performed. When recording the resting position, each volunteer kept the facial and masticatory musculature relaxed and lips in their habitual posture, with the examiner using the following command: Relax, relax, relax...

After this, to record isometric contraction, which was performed in maximum intercuspation, the volunteer placed parafilm material between the maxillary and mandibular teeth, bilaterally. The following verbal command was established: Force, force, force... Maintained for 10 seconds. To record isotonic contraction, non habitual masticatory activity, parafilm was used in the same way as in the previous movement and the masticatory cycle was determined by means of a metronome with a beat frequency of 60 bpm. The volunteer was instructed to bite the parafilm for 10 seconds whenever the sound of the metronome was heard.

After data collection, the electromyographic tracings were evaluated, and intervals were selected for analysis with each interval corresponding to 1 second. In the resting position and in isometric activity, 3 central intervals from the electromyographic tracing were selected, avoiding the initial and final intervals, as these may be influenced by the volunteer's initial hesitation,

TABLE 1 - Mean RMS (μ V) and standard deviation values with reference to the orbicularis oris muscle, upper segment (UO), of the groups with Class II, Division 1 and normal occlusion, in the resting, isometric and isotonic positions.

	Group			
	Class II, Division 1		Normal Occlusion	
	Mean	SD	Mean	SD
Rest	8.84 Ac	4.79	5.27 Bc	2.37
Isometry	27.66 Aa	23.64	17.83 Ba	8.41
Isotony	21.39 Ab	16.19	14.32 Bb	8.55

Means followed by different letters (capitals in the horizontal and lower case in the vertical) differ among them by ANOVA and the Tukey test ($p < 0.05$).

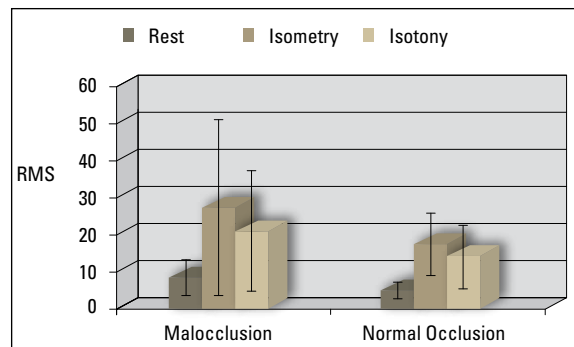


FIGURE 1 - Mean RMS (μ V) and standard deviation values with reference to the orbicularis oris muscle, upper segment (UO), of the groups with Class II, Division 1 and normal occlusion, in the resting, isometric and isotonic positions.

TABLE 2 - Mean RMS (μ V) and standard deviation values with reference to the orbicularis oris muscle, lower segment (LO), of the groups with Class II, Division 1 and normal occlusion, in the resting, isometric and isotonic positions.

	Group			
	Class II, Division 1		Normal Occlusion	
	Mean	SD	Mean	SD
Rest	14.24 Ab	10.63	6.96 Bb	3.50
Isometry	30.63 Aa	13.24	19.90 Ba	9.43
Isotony	25.85 Aa	14.19	20.61 Ba	16.62

Means followed by different letters (capitals in the horizontal and lower case in the vertical) differ among them by ANOVA and the Tukey test ($p < 0.05$).

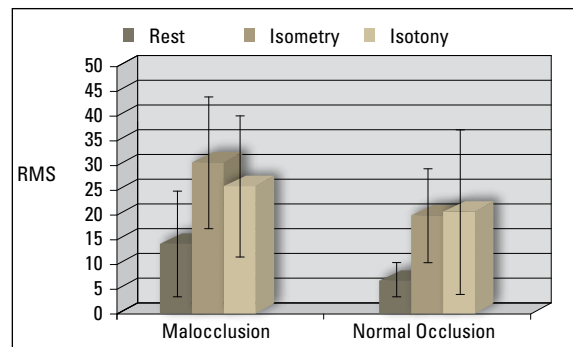


FIGURE 2 - Mean RMS (μ V) and standard deviation values with reference to the orbicularis oris muscle, lower segment (LO), of the groups with Class II, Division 1 and normal occlusion, in the resting, isometric and isotonic positions.

or diminished muscle activity at the end of the movement. In isotonic activity, one interval of the collected electromyographic tracing was selected, also avoiding the initial and final intervals.

The collected data were processed by the RMS (Root Mean Square) using Myosystem-I software, and submitted to statistical analysis by the analysis of variance (ANOVA) for repeated measures and the Tukey test ($\alpha = 0.05$).

RESULTS

The data with reference to electromyographic analysis are shown in Tables 1 and 2 and Figures 1 and 2.

The results revealed that there was statistically significant difference between the two studied groups, so that youngsters with Class II, Division 1 presented a higher mean value of electrical activity of the orbicularis oris muscle than youngsters with normal occlusion, in all the evaluated positions. Greater electrical activity occurred during isometric contraction than in isotonic contraction, however, this difference was not shown to be statistically significant for the lower segment of the orbicularis oris muscle. Discrete muscular activity was observed both in the group with Class II, Division 1 and in the group with normal occlusion during the resting position.

DISCUSSION

In this study, it was chosen to evaluate a group of youngsters in the age-range from 8 to 10 years, of the female gender, with dental Class II, Division 1, comparing them with a similar group with normal occlusion, as a great demand for treatment for this type of malocclusion has been observed in daily clinical practice. It is believed that orthodontic intervention in this age-range is more efficient because of greater tissue viscoelasticity, thus contributing to post-treatment stability. The choice of girls was made with the intention of avoiding variables that could interfere in the results due to inherent differences in development between the genders.

Electromyography is an extremely useful tool in the study of neuromuscular aspect of the masticatory system. Nevertheless, to obtain a faithfully electromyographic recording it is imperative to use an adequate technique in order to minimize the interferences from the environment.

In electromyographic signal acquisition surface electrodes were used. The choice of electrodes depends on the information one wishes to collect and the location of the muscles to be studied. Surface electrodes are used in the study of muscles located immediately under the skin, as they allow the integrated electrical activity of these muscles to be estimated, whereas needle electrodes enable access to deeper muscles, making them important in the study of motor units.^{15,16,20,21} In addition, surface electrodes have been shown to be easy to use and cause no discomfort to the patient.^{3,20}

In processing the collected signal, it was chosen to determine the RMS. This form of analysis presents outstanding advantages, since muscle electrical activity is expressed quantitatively, with this calculation made in a simplified manner by means of specific types of software.^{3,21}

In the present study there was evidence of a difference in electromyographic activity between youngsters with Class II, Division 1 and normal occlusion, with greater electrical activity of the

muscles in the group with malocclusion. This fact is probably related to the characterization of this malocclusion; that is, projected maxillary incisors and anteroposterior discrepancy, which makes it difficult for this musculature to perform its basic functions, generating the need for adaptations. The results obtained are in agreement with those of previous studies, in which the authors observed that patients with Class II, Division 1 expend greater perioral musculature effort to make various movements,^{11,19,24,25,27} in addition to presenting lower action potentials of the orbicularis oris muscle than those patients with normal occlusion; and that reduction in adequate dental contacts in the anterior region caused hypotonicity of the upper lip.^{1,12}

Some studies have also verified adaptations of the perioral muscles, with an increase in their activity in the presence of alterations such as sucking habits, predominantly mouth breathing and abnormal swallowing.^{2,6,14,22,23,26,29}

There are many reports in the literature about the importance of the perioral musculature as an etiologic factor of malocclusions.^{9,13,18,29,30} However, it was observed that there is great difficulty in evaluating the real participation of this musculature in determining the positions of teeth. The lip length presents no correlation with the degree of maxillary incisor protrusion.¹⁴ There is no direct correlation between the shape of the maxillary dental arch and perioral muscle activity¹⁹ but there is a possible impact of activity of the orbicularis oris muscle on the final position of teeth in the dental arches, especially in Class II, Division 1 and Division 2.¹⁰ Larger lip thickness could possibly cause greater muscular activity, but not necessarily influencing the position of teeth or inclination of incisors.¹⁷ Persistence of the pattern of perioral muscle dysfunction after orthodontic treatment may cause relapse.²² Imbalance of the perioral musculature represents a powerful factor in deformation of the arches and position of teeth.⁴ The orbicularis oris muscle influences the angulation of the maxillary incisors, however, it is not influenced by the degree

of maxillary protrusion.⁷ However, there appears to be no doubt that the upper and lower segments of the orbicularis oris muscle function in an independent manner.^{5,14,18,30}

In view of the results obtained in this study, it is believed that patients with Class II, Division 1 present a pattern of perioral muscle activity that differs from those with normal occlusion, with the need for greater muscle fiber participation to perform various functions.

CONCLUSIONS

Based on the literature, sample characteristics, methodology used and results obtained, it was concluded that:

1) Different electromyographic activity occurred between youngsters with Class II, Division 1 and those with normal occlusion.

2) This activity was shown to be greater in youngsters with Class II, Division 1, thus, suggesting decreased lip competence in this group.

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Comparative cephalometric study of dentofacial patterns of individuals with normal occlusion and Angle malocclusions

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Abstract

Objective: To evaluate dentofacial patterns of patients with normal occlusion and Angle malocclusions, examining potential differences between specific cephalometric measures as they relate to gender, both intra- and intergroup. **Methods:** The sample consisted of 200 lateral cephalometric radiographs obtained from young Brazilians of both genders, aged between 11 years and 2 months and 19 years and 10 months, with permanent dentition. The material was divided according to the type of occlusion into five groups: One group consisted of patients with normal occlusion and four groups of patients with Angle malocclusions, and each group was also divided by gender. Angular and linear cephalometric measures were evaluated. **Results:** Genders did not differ in most measures. Position of the maxilla showed no significant differences between groups. Mandibular retrognathia was remarkable in groups with Class II, Divisions 1 and 2. Vertical imbalances were observed with some significant differences. The pattern was found to be hypodivergent for groups with normal occlusion and Class II, Division 2, and neutral for groups with Class I; Class II, Division 1 and Class III. Dentoalveolar compensation was evident in groups with Class III and Class II, Division 2. Finally, the normal occlusion group profile was more convex than the patterns found in the US population. **Conclusions:** In general, some features of facial morphology were associated with certain types of malocclusion. However, individual assessment of each face is still necessary as some of the features are shared across different types of occlusion.

Keywords: Cephalometry. Malocclusion. Growth.

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INTRODUCTION

Despite the widespread influence of US orthodontics, with its standards and references, it is known that these do not apply to the ethnically mixed Brazilian population.²³ Facial profiles have often been compromised due to little or no importance given to the analysis of soft tissues. In contemporary orthodontics, attention to the soft tissues of the face has prevailed over all other types of complementary exams. With the advent of facial pattern classification into Classes I, II and III^{8,26} based on the facial characteristics of each patient, diagnostic data have become more meaningful when added to the numerous analyses^{5,15,18,22,23,24,27,28} that serve as input for the understanding of dental and facial components and their relationship with malocclusions.

With this in mind, it is understandable that knowledge of facial growth pattern provided by certain cephalometric analyses^{27,28} can also be very useful in establishing diagnosis, treatment plan and prognosis based on the outcomes of orthodontic treatment. Insight into how the variables of the craniofacial complex can contribute to the development of malocclusion, and that there are various manners in which parts of the skull and face (taken as normal in isolation) can form, in conjunction, an undesirable combination, can evidence the role and integration of each variable⁹ in facial morphology. The aims of this study were to assess whether or not there are statistically significant differences among five groups in terms of gender of subjects with normal occlusion and Angle malocclusions; to identify the various facial growth patterns; to determine, in the sagittal direction, which skeletal components contributed most to the characterization of Class II, Division 1, Class II, Division 2 and Class III malocclusions; to detect potential vertical changes; to determine the role of dentoalveolar compensations; and to identify the features of facial profile.

MATERIAL AND METHODS

Sample

Two hundred cephalometric radiographs were obtained from young Brazilians with no previous orthodontic treatment and with permanent dentition. All were Caucasian students whose Brazilian-born parents were of Mediterranean descent. Subjects were from both genders and attending different schools in the city of São Paulo, ABC region, and in the city of Santos. The sample was divided into five groups according to the occlusion types, i.e., one group of individuals with normal occlusion and four groups of individuals with malocclusions according to the concepts advanced by Angle.² Furthermore, each group was divided according to gender. The Ethics Committee of the Federal University of São Paulo/São Paulo Hospital reviewed and approved this research project referenced under CEP 0094/08.

Subjects with normal occlusion were selected by a clinical examination conducted in 7500 schoolchildren from the São Paulo ABC region.

» Group 1 (normal occlusion): Forty subjects (20 male and 20 female) with mean age of 15 years and 9 months (standard deviation ± 1 year and 7 months). ANB angle showed an overall mean of $2.01 \pm 1.90^\circ$. Sample selection comprised the clinical examination of the teeth in terms of healthiness, shape, size, position, presence of caries, adequate restorations and perioral tissue health. The anteroposterior relationship between dental arches was observed in the study models as well as the occlusal relationship between incisors, premolars and molars, the relationships between grooves and cusps, the axial inclination of teeth and appearance of the curve of Spee. Overjet and overbite were measured in the anterior region and any variation ranging from 0.5 to 4.0 mm was accepted as normal. In an occlusal view of the models, contact points, correct tooth positions, rotations and dental arch forms were observed. Facial soft tissues appeared well balanced and lips remained in contact when at rest.

» Group 2 (Angle Class I): Forty subjects (20 male and 20 female) with mean age of 14 years and 5 months (standard deviation ± 2 years). ANB angle exhibited an overall mean of $3.0 \pm 1.70^\circ$.

» Group 3 (Angle Class II, Division 1): Forty subjects (20 male and 20 female) with mean age of 14 years and 5 months (standard deviation ± 1 year and 11 months). ANB angle exhibited an overall mean of $5.39 \pm 2.33^\circ$.

» Group 4 (Angle Class II, Division 2): Forty subjects (20 male and 20 female) with mean age of 15 years and 3 months (standard deviation ± 2 years and 6 months). ANB angle displayed an overall mean of $4.56 \pm 1.80^\circ$.

» Group 5 (Angle Class III): Forty subjects (20 male and 20 female) with mean age of 15 years and 5 months (standard deviation ± 3 years). ANB angle displayed an overall mean of $-2.44 \pm 2.53^\circ$.

Methods

All cephalometric radiographs were obtained in right lateral view and centric occlusion. Cephalometric tracings were drawn over the radiographs using acetate paper and all anatomical details of interest to this study were highlighted. A pencil, protractor with 0.5° subdivisions, square and ruler with 0.5 mm subdivisions were used for cephalometric measurements.

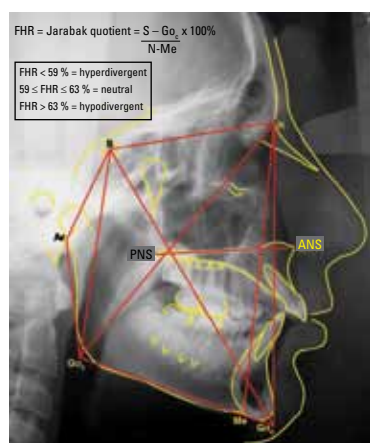


FIGURE 1 - S-N, S-Ar, Ar-Go_c, Go_c-Me, S-Go_c, N-Me, S-Gnc, N-Go_c, ANS-PNS and FHR.

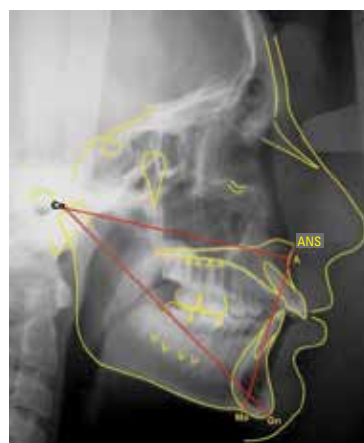


FIGURE 2 - Co-A, Co-Gn, ANS-Me.



FIGURE 3 - SNA, SNB, ANB, H-Nose, N.NB, IMPA, 1.PP.



FIGURE 4 - E-LL line.

Anatomical drawing, cephalometric landmarks, lines and planes were obtained and the following cephalometric measures evaluated: S-N, S-Ar, Ar-Go_c, Go_c-Me, S-Go_c, N-Me, S-Gn_c, N-Go_c, ANS-PNS, FHR, Co-A, Co-Gn, ANS-Me, SNA, SNB, ANB, H-Nose, H-NB, I.PP, IMPA, E-LL line (Figs 1, 2, 3 and 4).

Statistical method

The Kolmogorov-Smirnov test was initially applied and results showed normal distribution. For this reason, analysis of variance parametric test (ANOVA) was applied. The hypothesis test was used to assess whether there was any statistically significant difference between genders. Tukey's test was subsequently applied. A $p \leq 0.05$ significance level was adopted.

Method error

To assess method accuracy, 40 radiographs were selected at random from patients in the study sample ($n=200$). All radiographs were traced and measured again by a single examiner one month after the initial tracing. Paired t-test was then applied to assess systematic error. Once the difference between the first and second measurements had been obtained for each radiograph, Dahlberg's formula was employed to estimate random error.

RESULTS

Systematic error and random error are presented in Table 3. There were no statistically significant differences between genders for most of the measures studied (except lines H-Nose and E-LL in Class II, Division 1 cases). No statistically significant difference was found after comparison between groups regarding to the variable SNA.

In evaluating the variables across the five groups significant differences were found in the following comparisons: S-N (G1xG2, G1xG5, G2xG5, G3xG5 and G4xG5); S-Ar (G1xG5

and G4xG5); Ar-Go_c (G1xG2, G1xG3, G1xG4, G3xG5); Go_c-Me (G1xG2, G1xG3, G1xG4, G2xG5, G3xG5, G4xG5); S-Go_c (G1xG3, G1xG5); N-Me (G1xG4, G2xG4, G3xG4, G4xG5); S-Gn_c (G1xG3, G1xG4, G2xG3, G2xG4, G2xG5, G3xG5, G4xG5); N-Go_c (G1xG3, G1xG5, G2xG5, G3xG5, G4xG5); ANS-PNS (G1xG5, G2xG5, G3xG5, G4xG5); FHR (G1xG2, G1xG3, G1xG5, G2xG4, G3xG4, G4xG5); Co-A (G1xG2, G1xG5, G3xG5, G4xG5); Co-Gn (G1xG3, G1xG4, G2xG3, G2xG4, G2xG5, G3xG5, G4xG5); ANS-Me (G1xG4, G2xG4, G3xG4, G3xG5, G4xG5); SNB (G1xG2, G1xG3, G1xG4, G1xG5, G2xG5, G3xG5, G4xG5); ANB (G1xG3, G1xG4, G1xG5, G2xG3, G2xG4, G2xG5, G3xG5, G4xG5); H-Nose (G1xG3, G1xG5, G2xG3, G2xG5, G3xG4, G3xG5, G4xG5); H.NB (G1xG3, G1xG5, G2xG5, G3xG4, G3xG5, G4xG5); I.PP (G1xG4, G2xG4, G3xG4, G4xG5); IMPA (G1xG5, G2xG5, G3xG5, G4xG5); E-LL (G1xG3, G1xG4, G2xG4, G2xG5, G3xG4, G3xG5). The means of cephalometric measures (female, male and total) and the respective standard deviations for Groups 1, 2, 3, 4 and 5 are presented in Tables 1 and 2.

DISCUSSION

To facilitate reading, cephalometric measures will be discussed in topics. Due to the fact that no statistically significant differences were found between genders in most of the measures under study (except lines H-Nose and E-LL line in Class II, Division 1), the discussion was organized around the overall mean value of each measure in the five groups of the sample.

Sagittal evaluation of the basal bones

Among the factors that lend validity to cephalometric studies is their ability to quantify errors of discrepant samples by comparing them with normative values, which will

TABLE 1 - Means of cephalometric measures (female, male and total) and respective standard deviations for Groups 1 (normal occlusion) and 2 (Class I).

Measures	Group 1						Group 2					
	Male		Female		Total		Male		Female		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
S-N	77.10	3.06	74.00	2.90	75.55	3.34	73.08	3.87	72.48	3.74	72.78	3.77
S-Ar	38.50	3.59	34.48	2.44	36.49	3.65	36.13	2.27	33.73	3.25	34.93	3.02
Ar-Go _c	50.88	5.36	47.50	3.30	49.19	4.71	47.15	4.82	44.00	3.80	45.58	4.57
Go _c -Me	80.75	5.57	77.45	3.60	79.10	4.92	75.90	5.14	72.83	4.59	74.36	5.06
S-Go _c	85.48	6.81	78.50	3.81	81.99	6.49	80.55	6.28	75.03	4.24	77.79	5.98
N-Me	126.75	5.21	120.98	5.35	123.86	5.98	128.15	7.97	123.30	7.07	125.73	7.83
S-Gn _c	139.98	6.88	134.18	4.91	137.08	6.59	136.18	7.55	131.65	5.95	133.91	7.09
N-Go _c	129.03	6.64	120.88	4.24	124.95	6.88	123.55	7.50	117.83	5.16	120.69	6.98
ANS-PNS	57.78	3.03	55.73	2.00	56.75	2.74	55.85	3.07	54.98	2.91	55.41	2.99
FHR %	67.45	4.85	64.99	3.56	66.22	4.38	62.90	3.92	61.00	4.55	61.95	4.30
Co-A	98.80	4.30	94.05	2.86	96.43	4.33	93.05	5.13	91.68	6.03	92.36	5.57
Co-Gn	128.00	5.72	122.50	3.62	125.25	5.49	122.55	7.27	119.70	5.59	121.13	6.56
ANS-Me	69.63	4.72	67.55	4.43	68.59	4.64	70.13	6.07	67.20	6.09	68.66	6.18
SNA	81.35	2.56	81.98	1.85	81.66	2.23	79.85	3.15	79.65	5.09	79.75	4.18
SNB	79.45	2.77	79.85	2.60	79.65	2.66	76.95	3.06	76.55	4.75	76.75	3.95
ANB	1.90	2.04	2.13	1.79	2.01	1.90	2.90	1.77	3.10	1.67	3.00	1.70
H-Nose	5.53	4.82	5.93	4.59	5.73	4.65	3.33	5.09	5.03	4.49	4.18	4.81
H.NB	12.23	4.80	12.30	4.56	12.26	4.62	14.73	5.45	11.55	4.03	13.14	4.99
1.PP	108.40	6.18	112.60	6.18	113.33	6.15	115.85	6.77	113.48	7.16	114.66	6.98
IMPA	94.67	6.98	92.05	5.63	93.58	6.32	91.05	6.07	91.15	6.24	91.10	6.08
E-LL line	1.18	3.07	1.63	2.74	1.40	2.88	-1.00	3.54	0.75	3.39	-0.13	3.53

be determined in this study.²⁶ It is noteworthy, however, that in the same manner that balanced faces, defined as Pattern I, can present with any type of malocclusion, normal occlusion can be seen in facial Patterns II, III, Long and Short Faces with moderate discrepancies, susceptible to natural or orthodontic dental compensations.⁸ In this study, the occlusal characteristics employed to characterize the normal occlusion group (Group 1) were in accordance with the concepts advanced by Angle.² The average values of the ANB angle for females were 2.13° and for males 1.90°. In a qualitative facial analysis, all

individuals in this group showed balanced facial soft tissues with lips sealed at rest, although the pattern type was not taken into consideration.⁸ In assessing the composite values – McNamara's Regular Patterns – an adequate ratio was found in five female patients (n=20) and 5 male patients (n=20) for measures Co-A, Co-Gn and ANS-Me (25% of the sample), although, on average, cephalometric measures showed a good anteroposterior relationship between basal bones. No statistically significant difference was found in the sagittal position of the maxilla among the five groups under study. Other investigations^{7,30}

TABLE 2 - Means of cephalometric measures (female, male and total) and respective standard deviations for Groups 3 (Class II, Division 1), 4 (Class II, Division 2) and 5 (Class III).

Measures	Group 3						Group 4						Grupo 5					
	Male		Female		Total		Male		Female		Total		Male		Female		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
S-N	75.05	2.73	71.60	2.97	73.33	3.31	74.63	3.95	71.87	3.94	73.25	4.13	72.70	4.62	64.80	3.17	70.51	4.54
S-Ar	35.70	3.57	34.28	3.24	34.99	3.44	37.50	2.81	34.60	2.18	36.05	2.88	34.88	4.34	32.40	2.26	33.64	3.64
Ar-Go _c	43.65	4.14	45.05	5.32	44.35	4.76	46.20	5.10	45.07	3.56	45.64	4.38	49.23	7.47	42.93	5.43	47.26	6.79
Go _c -Me	71.10	5.80	71.78	3.67	71.44	4.80	73.50	4.67	72.10	5.84	72.80	5.27	80.45	7.21	76.30	5.15	78.38	6.53
S-Go _c	75.98	6.35	76.30	5.40	76.14	5.82	80.20	6.01	76.40	3.75	78.30	5.30	80.80	9.59	73.88	6.05	77.34	8.66
N-Me	123.70	5.89	119.53	6.55	121.61	6.50	119.38	5.62	112.57	4.80	115.98	6.20	126.25	9.58	119.53	7.42	122.89	9.12
S-Gn _c	129.48	7.06	126.60	4.90	128.04	6.17	127.08	5.71	120.57	5.36	123.83	6.38	143.40	11.09	135.73	9.20	139.56	10.79
N-Go _c	121.68	6.94	119.00	4.61	120.34	5.97	124.88	7.20	119.55	4.72	122.21	6.59	118.15	8.52	109.95	6.33	114.05	8.49
ANS-PNS	56.90	3.23	55.08	3.25	55.99	3.33	56.63	3.10	54.47	2.97	55.55	3.19	53.30	3.45	51.25	2.69	52.28	3.23
FHR %	61.43	4.44	64.04	5.82	62.73	5.28	67.24	5.01	67.90	3.04	67.57	4.10	64.05	6.31	52.43	4.43	62.96	5.58
Co-A	95.10	6.06	93.05	3.14	94.08	4.87	95.55	4.82	92.85	4.07	94.20	4.61	90.43	5.58	88.55	4.42	89.49	5.06
Co-Gn	116.65	7.13	116.80	5.37	116.73	6.23	118.50	4.64	113.05	4.77	115.78	5.40	129.90	9.46	124.05	8.86	126.98	9.52
ANS-Me	65.30	4.14	65.23	6.04	65.26	5.11	61.90	2.78	59.25	3.24	60.58	3.27	71.93	9.11	66.05	6.40	68.99	8.32
SNA	79.43	5.28	80.90	2.83	80.16	4.25	79.13	3.19	80.20	3.09	79.66	3.15	80.38	4.29	81.65	3.30	81.01	3.83
SNB	73.85	4.23	75.75	3.02	74.80	3.75	74.93	3.06	75.27	2.60	75.10	2.81	83.38	4.16	83.58	3.10	83.48	3.62
ANB	5.63	2.61	5.15	2.05	5.39	2.33	4.20	1.85	4.92	1.73	4.56	1.80	-3.00	2.83	-1.88	2.11	-2.44	2.53
H-Nose	-2.28	3.83	3.20	4.31	0.46	4.89	4.25	4.12	6.35	2.50	5.30	3.53	11.25	5.51	9.98	4.23	10.61	4.89
H.NB	18.03	5.25	14.23	3.85	16.13	4.93	13.00	6.92	12.57	3.29	12.76	5.36	3.75	6.17	4.48	4.98	4.11	5.55
1.PP	113.85	6.74	117.80	6.45	115.83	6.81	102.15	8.63	102.20	8.00	102.18	8.21	116.83	7.66	117.75	6.46	117.29	7.01
IMPA	94.67	5.46	93.95	4.50	94.31	4.95	96.95	7.51	95.15	6.18	96.05	6.85	81.47	6.69	79.50	6.72	80.51	6.69
E-LL line	-1.80	3.25	0.20	2.23	-0.80	2.93	2.95	2.47	4.22	2.57	3.59	2.57	2.23	3.95	2.38	2.96	2.30	3.45

have confirmed these findings in patients with Class II, Divisions 1 and 2.

In Group 5 (Class III), the maxilla was assessed by the palatal plane and Co-A distance, and showed the lowest means in relation to all groups. A study²⁹ involving Asian youths with Class III malocclusion showed significant differences in ANB values and in the effective length of the maxilla (Co-A) between the Class III and Class I groups, determining a skeletal maxillary retrusion in the Class III group. Although the sample used in this study comprises Caucasians, the results of the afore-

mentioned study²⁹ are in agreement with the results of this study.

As regards craniofacial growth, coinciding with the growth of the anterior cranial base, the maxilla migrates forward to a very similar extent, thereby keeping the SNA angle relatively constant.¹⁵ As described in the literature¹² and in agreement with it, there was a progressive and significant increase in all dimensions of the cranial base in the Class III group, going through the Class I group and proceeding through the Class II groups. Likewise, the anterior cranial base is reduced in Class III patients when

TABLE 3 - Method error (systematic and random).

Measures		1 st reading	2 nd Reading	Student's t-test (systematic error)	Dahlberg's formula (random error)
S-N	Mean	73.28	73.34	0.536	0.44
	SD	4.23	4.35		
S-Ar	Mean	35.24	35.19	0.421	0.27
	SD	4.09	4.04		
Ar-Go _c	Mean	47.30	47.24	0.342	0.29
	SD	5.29	5.32		
Go _c -Me	Mean	75.43	75.34	0.147	0.42
	SD	6.01	6.02		
S-Go _c	Mean	79.24	79.29	0.694	0.56
	SD	7.41	7.44		
N-Me	Mean	122.74	122.84	0.273	0.40
	SD	9.26	9.34		
S-Gn _c	Mean	134.36	134.43	0.453	0.37
	SD	9.98	9.90		
N-Go _c	Mean	120.16	120.11	0.512	0.34
	SD	8.57	8.52		
ANS-PNS	Mean	55.11	55.19	0.492	0.48
	SD	3.49	3.35		
FHR %	Mean	64.69	64.68	0.936	0.50
	SD	5.56	5.56		
Co-A	Mean	93.68	93.61	0.161	0.52
	SD	5.55	5.59		
Co-Gn	Mean	122.70	122.53	0.538	1.25
	SD	7.27	7.56		
ANS-Me	Mean	67.51	67.45	0.724	0.40
	SD	8.30	8.42		
SNA	Mean	81.18	81.28	0.390	0.51
	SD	3.03	2.96		
SNB	Mean	78.69	78.63	0.767	0.56
	SD	4.04	4.13		
ANB	Mean	2.50	2.65	0.343	0.70
	SD	3.09	3.22		
H-Nose	Mean	4.74	4.65	0.484	0.22
	SD	5.45	5.50		
H.NB	Mean	12.10	12.06	0.637	0.35
	SD	5.33	5.40		
I.PP	Mean	113.90	113.99	0.360	0.42
	SD	8.69	8.72		
IMPA	Mean	91.50	91.34	0.085	1.68
	SD	7.82	7.71		
E-LL line	Mean	0.71	0.71	0.928	0.70
	SD	3.53	3.56		

compared with normal occlusion.¹³ Thus, using the anterior cranial base as a reference is unreliable since it can alter the reading of angles SNA, SNB and ANB.

The position of the mandible (SNB) in Group 2 (Class I) showed a slight retrusion with the ANB angle showing statistical differences relative to Groups 3 and 4 (Class II, Divisions 1 and 2) and Group 5 (Class III). Effective mandibular length (Co-Gn) and Go_c-Me distance in Group 3 (Class II, Division 1) were decreased as well, with statistical differences found in comparison with Group 1 (normal occlusion), a result also found in other studies.^{19,20} The mandible showed marked retrusion, very similar to the patients in group 4 (Class II, Division 2). As a result, a sagittal discrepancy was found between the basal bones, which increased angle ANB.^{3,4} These findings corroborate the results of investigations^{14,22} that studied a clinical population suffering from Class II malocclusion and found that, on average, the maxilla was in a neutral position and, whenever that was not the case, it was positioned more retrusively than protrusively. Investigators further argued that mandibular skeletal retrusion was the most common feature in the Class II sample. Results from another study⁶ also revealed that mandibular length was greater in the normal occlusion group compared with the Class II, Division 1 group. Facial length (S-Gn_j) was reduced due to the small size of the mandible in Groups 3 and 4 (Class II), unlike the other groups. Facial depth (N-Go_j) showed in Group 4 (Class II, Division 2) values that were similar to those in Group 1 (normal occlusion) probably owing to the fact that these two groups had hypodivergent facial growth.

In Group 5 (Class III) patients, distances Co-Gn and Go_c-Me showed significant differences relative to all groups except Group 1 (normal occlusion). In the sagittal direction, the mandible was found to protrude (SNB)

and, again, it should be noted that anterior cranial base shortening, often present in Class III patients, can affect SNB angle reading. Facial length (S-Gn_j) was also higher in Group 5 (Class III) when compared with other groups while facial depth (N-Go_j) produced the lowest mean, probably due to the possible retraction of point nasion.

Vertical evaluation of the basal bones

Group 1 (normal occlusion) showed, on average, hypodivergent facial growth with counterclockwise rotation.²⁸ Fourteen female patients displayed a hypodivergent pattern and 6 were neutral (n=20), with a mean of 64.99% (59.44% minimum and 73.5% maximum) and 16 males were hypodivergent, 3 were neutral and 1 hyperdivergent (n=20), with a mean equal to 67.45% (58.8% minimum and 76.89% maximum). Distances S-Ar and Ar-Go_c achieved the highest overall means. Each time the ratio between posterior cranial base and mandibular ramus height approaches 1:1, this will point to the existence of a short branch.¹⁵ The ratio between distances S-Ar and Ar-Go_c in this group was 1:1.34, which is indicative of increased ramus height and greater counterclockwise rotation of the mandible, a pattern that favors a hypodivergent pattern.

Assessment of Jarabak analysis disclosed that patients in Group 2 (Class I) had a neutral facial growth pattern, according to prior studies.^{1,5,28} Concerning anterior facial height (N-Me), some investigations^{9,16} have shown that in male subjects this dimension is typically larger than in females, which is confirmed by the findings of this study. When changes occur in anterior facial proportions, lower facial height (ANS-Me) contributes most to these changes^{11,17} while upper facial height remains virtually unaltered.

In Group 3 (Class II, Division 1), posterior facial height (S-Go_j) displayed the lowest mean of all groups under study. Assessment of Jarabak

analysis indicated that Group 3 (Class II, Division 1) had a neutral facial growth, corroborating the findings of Siriwat and Jarabak.²⁸

In Group 4 (Class II, Division 2) both maxilla and mandible showed anteroposterior discrepancy of apical bases, which was masked not only by a marked decrease in antero-inferior facial height (ALFH) but also by reduced anterior facial height (N-Me). These two measures showed statistical differences, with Group 4 (Class II, Division 2) exhibiting the lowest means in relation to the groups under study.

Posterior cranial base length, represented by measure S-Ar, was increased similarly to the values of Group 1 (normal occlusion), and ramus height (Ar-Go_j) showed a statistically significant difference compared to the same group. The combination of posterior and anterior facial heights resulted in a hypodivergent²⁸ facial growth pattern in this malocclusion group. Judging from the results, it appears that anticlockwise rotation of the mandible is more associated with reduced anterior facial height than with excessive posterior facial height. Group 4 (Class II, Division 2) was characterized by a short anterior facial height accompanied by excessive overbite.¹⁸ The results of this study are consistent with other investigations^{1,7,25,28} which also found hypodivergence in this malocclusion group. On the other hand, a research²⁴ has shown that in individuals with Class II, Division 1 and Class II, Division 2, both hypo- and hyperdivergent patterns can be found. The authors²⁴ concluded that, except for the position of maxillary incisors, there is no basic difference in dento-skeletal morphology between Class II, Division 1 and Class II Division 2 malocclusions. In this sample, 33 out of 40 subjects (82.5%) in Group 4 (Class II, Division 2) were found to display a hypodivergent growth pattern and only seven (17.5%) had a neutral pattern. Group 3 (Class II, Division 1) showed that 19

of 40 subjects (47.5%) had a hypodivergent pattern, 13 (32.5%) had a neutral patterns and 8 (20%) were hyperdivergent. Current results do not confirm the findings of Pancherz et al²⁴ since in this sample no hyperdivergent cases were found in Group 4 (Class II, Division 2). Another important aspect to consider in the above study is its sample size²⁴ of 347 subjects with Class II, Division 1 malocclusion and 156 with Class II, Division 2. This study comprised 40 Class II, Division 1 and 40 Class II, Division 2 cases. Some authors¹⁸ define two different types of Class II, Division 2 malocclusion: The “easy” type, with a long mandibular ramus, also called mandibular brachyfacial typology, and the “difficult” type, with a short mandibular ramus or mandibular dolichofacial typology.

In Group 5 (Class III), anterior facial height (N-Me) showed a statistically significant difference compared to Group 4 (Class II, Division 2). Posterior cranial base length (S-Ar) showed reduced values for all groups. The combination of posterior (S-Go_j) and anterior (N-Me) facial heights resulted in a neutral facial growth pattern. In contrast to the results of this research, Siriwat and Jarabak²⁸ found a hypodivergent growth pattern in Class III patients.

Dentoalveolar position

In assessing maxillary incisors position in Group 1 (normal occlusion) in light of measure I.P.P, a mean of 112.60° (minimum 103° and maximum 127°) was found for the female gender and 113.90° for males (minimum 100° and maximum 128°).

In evaluating mandibular incisors position, IMPA showed a mean of 92.5° (minimum 86° and maximum 99°) for females and 94.67° (minimum 79° and maximum 107°) for males. Incisor position is best evaluated in relation to their basal bones by means of the angles formed between maxillary incisors and the palatal plane, and between mandibular incisors

and the mandibular plane. These measures prevent sagittal errors in the basal bones from undermining the evaluation of dental positions.²⁶ This research yielded an overall mean for 1.PP (113.25°) that was greater than the one advocated by Schwartz (110°), but in agreement with the findings of Reis et al²⁶ (115.2°), although these authors examined a sample of Pattern I individuals, i.e. normal individuals with malocclusion, but without skeletal discrepancy.⁸ The results of the study sample showed mandibular incisor inclination (overall mean = 93.58°) in agreement with other results found in the literature.^{21,26} The overall mean for angle ANB was 2.01° (ranging from -2° to 5.5°) and the skeletal discrepancies found in some cases were offset by the position of maxillary and mandibular incisors, in attempting to reach facial balance.

As regards the groups with malocclusion, the dental compensations in Groups 4 and 5 (Class II, Division 2 and Class III) are worthy of note. The results of Group 4 (Class II, Division 2) confirm previous investigations,^{7,24} which also found retroclination in maxillary incisors. In Group 5 (Class III), dentoalveolar compensation took place, especially when maxillary incisors were evaluated relative to the palatal plane (increased 1.PP), although statistically significant differences were only found in comparison with Group 4 (Class II, Division 2). Moreover, the lower incisors, in relation to mandibular plane (IMPA), had their values decreased and statistically different from all other groups. As can be observed, dental compensation was more a result of the relationship between mandibular and maxillary incisors. Group 3 (Class II, Division 1) exhibited a higher dental protrusion than all other groups.

Facial profile

Group 1 (normal occlusion), after evaluation of H-Nose (mean = 5.73 mm) and H.NB

(mean = 12.26°), showed a tendency toward a more convex profile due to a greater protrusion. Regarding the distance from lower lip to Ricketts esthetic plane, a mean 1.4 mm was found (15 years and 9 months). This distance increased at a rate of 0.2 mm per year, and at 8 years and 6 months should be equal to 2 mm.²⁷ According to Ricketts, at 12 years it should measure -2.8 mm, at 13 years, -3 mm, and at age 14, -3.2 mm. Corroborating the results of this study, Nobuyasu et al²³ also found that the lower lip was positioned more anteriorly compared to the standard recommended by Ricketts. This is due to a greater protrusion found in the samples under study, probably owing to a greater ethnical miscegenation of Brazilian Caucasians.²³

Groups 3 and 4 (Class II, Divisions 1 and 2) exhibited mandibular retrusion, as mentioned earlier. Group 3 (Class II, Division 1) displayed a more convex profile than all other groups. In Group 4 (Class II, Division 2), the facial profile was similar to values found for Group 1 (normal occlusion) due to reduced anterior facial height, which caused mandibular rotation in a counterclockwise direction and masked the mandibular deficiency. Assessment of the influence of mandibular position on facial esthetics has determined that Class I malocclusion patients with normal vertical pattern¹⁰ exhibited the most pleasant profile. Group 5 (Class III) had the most concave profile owing to sagittal discrepancy of the apical bases (mandibular excess, maxillary deficiency or a combination of both factors).

CONCLUSIONS

1) Normal occlusion and Class II, Division 2 malocclusion groups presented a hypodivergent growth pattern, while Class I; Class II, Division 1, and Class III malocclusion groups showed a neutral growth pattern, according to Siriawat and Jarabak.

2) Sagittal mandibular retrognathism was the most common feature found in the Class II, Divisions 1 and 2 malocclusion groups. In the group of Class III malocclusion, due to the shortening of the anterior cranial base, sagittal assessment through angles SNA and SNB was compromised, though the size of the maxilla was decreased in light of the measures under study (Co-A and ANS-PNS).

3) The greatest dental compensations occurred in response to Class III and Class II, Division 2 malocclusions.

4) The facial profile in the Class II, Division 1 malocclusion group exhibited greater convexity while the lower lip crossed Ricketts E line. The normal occlusion group showed a profile more convex than the patterns found in the US population.

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Effects of nickel-titanium and stainless steel leveling wires on the position of mandibular incisors

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Abstract

Objective: Investigate the effects of heat-activated NiTi and stainless steel wires to evaluate potential changes in the position of mandibular incisors in extraction cases as correlated with treatment length. **Method:** The sample consisted of 36 individuals of both genders, Brazilian Caucasians with mean initial age of 15 years and 5 months with Class I and Class II malocclusions, divided into two groups. In Group 1 (n=17) leveling was performed with Sequence 1, comprised of three different wire cross-sections: 0.016-in and 0.019 x 0.025-in heat-activated NiTi wires and 0.019 x 0.025-in stainless steel wires. In Group 2 (n=19) Sequence 2 was tested using only stainless steel wires (0.014-in, 0.016-in, 0.018-in, 0.020-in and 0.019 x 0.025-in) with passive torque in the mandibular incisors. Data were collected using computerized cephalometry and compared using Student's t-test with 5% significance level. **Results:** In Group 1, mandibular incisors were inclined lingually although only the crowns showed significant movement (1.6 mm). In Group 2, mandibular incisors remained stable. No vertical changes were noted in either group. **Conclusions:** Sequence 2 yielded better mandibular incisor control with no changes in their initial positions, while Sequence 1 allowed torques in the bracket prescription to be expressed, leading to the lingual inclination of these teeth. Treatment length was shorter when Sequence 1 was used. The evaluated biomechanic variations presented advantages and disadvantages that should be known and considered by the orthodontist during treatment planning.

Keywords: Leveling. Orthodontic wires. Biomechanics.

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INTRODUCTION

Leveling can be defined as the first active phase of orthodontic treatment and involves correction of individually malpositioned teeth, bracket slot leveling, correction of tooth arch discrepancy, initial correction of the curve of Spee, and torque adjustment.^{9,16,20} Uncontrolled tooth movements during leveling – which lead to anchorage loss and destabilize mandibular teeth – can decisively affect the achievement of the best goals set in orthodontic plan. Therefore, tooth movement planning becomes essential and plays an important role from the beginning of malocclusion correction.

Defining the wire sequence to be used in leveling can vary depending on technique, type of brackets, practitioner preference and treatment goals. In theory, this selection should allow a progression of less rigid wires in the early stages to enable dental alignment, and then more rigid rectangular wires in the final stages to three-dimensionally control dental movements.^{1,5} The ideal orthodontic archwire should be able to produce light forces delivered at constant levels, thereby providing optimal conditions for tooth movement with minimal discomfort to the patient, with no tissue hyalinization or root resorption.^{6,16}

Within the current context, four types of alloys are most commonly used by orthodontists: Stainless steel, nickel-titanium, cobalt chromium, and beta-titanium. The former two types are more commonly used in leveling. Stainless steel first became available in the 40's and since then has been successfully used in orthodontics. It still remains popular due to its low cost, excellent formability, weldability and good mechanical properties. It features relatively greater hardness than most of today's materials.⁶

The first nickel-titanium (NiTi) alloy was developed by the U.S. Naval Ordnance Laboratory space program and was named Nitinol.¹⁵ The emergence of this alloy significantly contributed

to the advancement of treatment mechanics, primarily associated with pre-adjusted appliances.^{2,13} NiTi alloys have been widely used during the early phases of orthodontic treatment and are especially well indicated for clinical situations that require great flexibility and elastic memory. They also feature low hardness, high work potential while producing low levels of force. However, they have limited formability, produce high frictional forces and cannot be so effectively welded.^{6,15}

Currently, NiTi alloys fall into three subdivisions: A conventional alloy (NiTi classic) and two superelastic alloys (pseudoelastic and thermoelastic), each with its unique properties.^{6,15} The superelastic feature means that the wire deliver the same force regardless of the degree of activation.² Due to its versatility, provided by a combination of shape memory, excellent mechanical properties, biocompatibility and delivery of constant forces, the use of superelastic NiTi is widespread in orthodontics.^{6,17} For some authors, superelastic NiTi archwires have potential advantages compared to conventional stainless steel archwires as they enable the application of a constant level of force during tooth movement.^{6,7,15,17} Conversely, several clinical studies that evaluated the properties of routinely used orthodontic archwires demonstrated no significant advantage in the ability of superelastic NiTi wires to align teeth, even in comparison with NiTi classic wires or multistrand steel wires.³

Therefore, the reason to use more expensive NiTi wires seems to lie in the fact that they deliver lighter forces,^{13,17} although there is some controversy in the literature regarding their ability to provide continuous forces. According to some authors, in clinical practice NiTi wires are rarely deformed enough as to allow their superelastic properties to be fully utilized.^{3,15,17} Another application of superelastic alloys is the use of rectangular wires in the early stages of leveling.

The purpose would be to provide three-dimensional tooth movement control from the start of treatment, thereby developing controlled force levels.¹⁷

In general, in reviewing the literature one finds that despite considerable interest in laboratory experiments there is a lack of *in vivo* studies to support the choice of a wire sequence. This scarcity is due to difficulties in assessing (a) the behavior of different alloys and (b) the force they deliver within the oral environment.¹⁰

This study was conducted in order to shed light on the effects produced by activated NiTi wires compared to the effects produced by stainless steel wires in evaluating potential changes in the position of mandibular incisors during leveling. Thus, two different sequences of orthodontic wires were used and correlated with treatment time.

MATERIAL AND METHODS

Material

Sample

The sample consisted of 36 Brazilian Caucasian research subjects (20 women and 16 men) with Class I and Class II malocclusions, complete natural dentition, with the exception of third molars. The mean age of the sample at the start of treatment was 15 years and 5 months and ranged from 13 years and 8 months to 17 years and 5 months. Mandibular first premolar extraction was indicated for all patients. The sample was divided into two groups: Group 1 consisted of 17 individuals whose leveling was performed using a sequence of three orthodontic wires, named Sequence 1: 0.016-in and 0.019 x 0.025-in of heat-activated NiTi wires and 0.019 x 0.025-in stainless steel wires; and Group 2 consisted of 19 individuals whose leveling was performed with Sequence 2, comprising only stainless steel wires: 0.014-in, 0.016-in, 0.018-in, 0.020-in and 0.019 x 0.025-in with passive torque in the mandibular incisors.

This research project was approved by the Ethics Committee of the School of Dentistry, University of São Paulo.

Methods

Orthodontic treatment

Orthodontic treatment of the sample subjects under study was performed by students enrolled on the orthodontics graduate courses, at Master's and PhD levels. Before starting treatment, the protocol for the clinical procedures adopted in this research was thoroughly debated in seminars by the faculty responsible for clinical research and operators.

Orthodontic treatment was performed with the extraction of first premolars using as anchorage a lingual arch made of 0.9 mm wire and welded to the mandibular first molar bands. Pre-adjusted orthodontic appliances were used (0.022 x 0.028-in Victory series brackets, 3M Unitek, Monrovia, CA, USA) in the MBT prescription, with 6° of lingual torque in the mandibular incisor crowns. Given the negative tooth arch discrepancy found at the beginning of orthodontic treatment, lacebacks were placed during leveling to trigger canines retraction and create space for incisors alignment. The lacebacks were reactivated every 21 days on average.

In Group 1, leveling was started with 0.016-in and 0.019 x 0.025-in OrthoForm II heat-activated NiTi wires (3M Unitek, Monrovia, CA, USA). Thereafter, 0.019 x 0.025-in stainless steel archwires were engaged. Each archwire was used for approximately 90 days and average leveling time was 11 months. In Group 2, the first wire used (0.014-in) was passively inserted in the bracket slots by means of 1st and 2nd order bends, copying the improper tooth positioning. From then on the bends were progressively decreased at each visit until passive wire engagement became possible without the need for any bends. No bends were placed in any of the other archwires, which were replaced

whenever their tooth-moving potential was exhausted. The 0.019 x 0.025-in archwire was inserted passively in the mandibular incisor bracket slots. To this end, some lingual torque was added to this region to neutralize the -6° torque present in the mandibular incisors, as prescribed by the MBT technique.¹¹ In this group, the mean leveling time was 21 months.

In both groups the round archwires were bent on the distal side of the second molar tubes. Passive lacebacks were placed over the rectangular stainless steel archwires, extending from the hooks welded between canines and lateral incisors to the hooks on the second molar tubes. Steel archwires were individually diagrammed according to the method proposed by McLaughlin, Bennett and Trevisi.¹¹ Leveling was considered complete when the 0.019 x 0.025-in stainless steel archwires exhibited a passive engagement in the tubes and brackets.

Computerized cephalometry

Two lateral cephalograms were made for each subject in the sample, one at the beginning (T_0) and one at the end (T_1) of the leveling phase. The radiographs were obtained by orienting each patient's head in a head holder to ensure parallelism between the Frankfort plane and the ground. The ear rods were placed in the external auditory meati with light pressure and the anterior vertical rod was set to touch the region between the nasal and frontal bones. The radiographs were taken with the mouth open for better visualization of dental structures. The distance from the X-ray source to the midsagittal plane of the head was 1.52 m and the distance between the film cartridge holder and the face was set as short as possible. Image magnification was set at 10%. The X-ray films were processed in an automatic processor.

The study of possible dental changes occurring during leveling was conducted using computerized radiographic cephalometry. Initially, the

radiographs were scanned with 300 dpi resolution, grayscale mode, 8 bits, JPEG format at 1:1 ratio, as recommended by Ongkosuwito et al.¹⁴ Cephalometric measurements were then obtained using Radiocef software, Version 4.0 (Radio Memory, Belo Horizonte, MG, Brazil). The use of computerized cephalometry allowed the landmarks, lines and cephalometric measurements to be identified directly on the digitized radiographic image, thereby rendering unnecessary the drawing of anatomical tracings.

Study of changes in the position of mandibular incisors

For this study two cephalometric landmarks were identified:

- » C1 – Superior-most point on the crown of the mandibular right central incisor.
- » R1 – Inferior-most point on the root of the mandibular right central incisor.

The mandibular plane (Go-Me) was used as horizontal reference and the symphysis line was used as vertical reference, perpendicular to the mandibular plane passing through the posterior-most point of the mandibular symphysis (S). To evaluate the position of the mandibular incisors four linear measurements were employed, starting at points C1 and R1 and extending perpendicularly to the horizontal and vertical reference lines (C1-S, C1-PM, R1-S and R1-PM). The angle formed by the long axis of the mandibular central incisor and the mandibular plane (C1-R1.PM) was also observed (Fig 1).

Error analysis method

To assess potential operational errors, the study was repeated in all sample subjects starting at the stage of cephalometric landmark identification by the same operator, with a minimum 15-day interval. Dahlberg's formula was adopted to determine random error. Systematic error was evaluated by Student's t-test for paired samples⁸ with a 5% significance level. Random errors

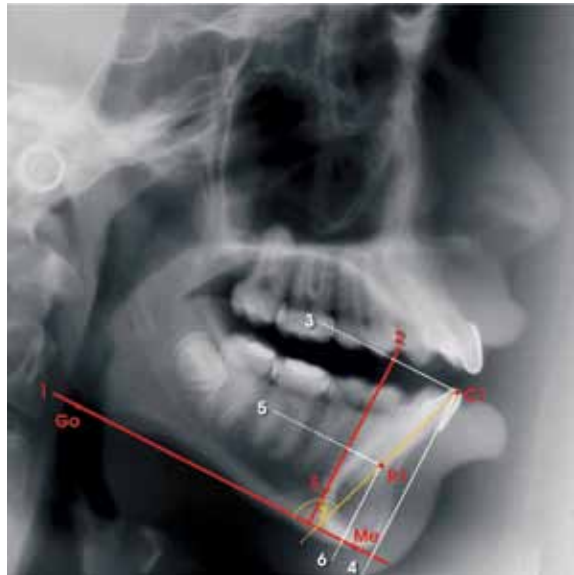


FIGURE 1 - 1) Mandibular plane; 2) symphysis line; 3) C1-S; 4) C1-PM; 5) R1-S; 6) R1-PM and 7) C1-R1.PM.

showed no variations greater than 0.74 mm for linear measurements (R1-S) and 1.6° for angular measurements (C1-R1.PM). Regarding systematic errors, a significant difference was found only for measure R1-S. In this case, however, the difference was minor and related to the root apex of the mandibular central incisor, which is a complex structure and hard to identify in lateral radiographs¹⁸.

Statistical method

Central tendency and dispersion measurements were obtained (arithmetic mean and standard deviation) of the measures under study for phases T_0 and T_1 . Within each group, means were compared using Student's t-test for paired samples. Central tendency and dispersion measurements (average and standard deviation) were calculated for the differences

between the means at phases T_0 and T_1 in Groups 1 and 2, which were compared using Student's t-test for independent samples. A 5% significance level was adopted.

RESULTS

The outcome data are presented in Tables 1, 2 and 3.

TABLE 1 - Mean, standard deviation (SD), difference between means and comparison between means (P) of variables in Group 1.

Group 1	T_0		T_1		Difference between means	P
	Mean	SD	Mean	SD		
C1-S	7.91	2.22	6.24	2.31	-1.67	0.028*
C1-PM	42.14	3.22	42.67	3.74	-0.53	0.422
R1-S	4.91	1.38	4.97	1.43	0.06	0.623
R1-PM	21.44	3.66	21.30	3.79	0.14	0.402
C1-R1.PM	97.71	4.80	93.41	4.37	-4.30	0.014*

* Statistically significant difference.

TABLE 2 - Mean, standard deviation (SD), difference between means and comparison between means (P) of variables in Group 2.

Group 2	T_0		T_1		Difference between means	P
	Mean	SD	Mean	SD		
C1-S	7.10	4.32	6.51	3.99	0.59	0.118
C1-PM	45.34	4.27	45.56	4.69	-0.22	0.397
R1-S	4.99	2.03	4.81	2.35	0.18	0.533
R1-PM	22.54	3.79	22.70	4.28	-0.16	0.588
C1-R1.PM	95.28	7.69	94.45	6.81	0.83	0.554

TABLE 3 - Difference between means, standard deviation (SD) and comparison of differences between means (P) for Groups 1 and 2.

T_0-T_1	Group 1		Group 2		P
	Mean	SD	Mean	SD	
C1-S	-1.67	1.39	0.59	1.57	0.031*
C1-PM	-0.53	0.70	-0.22	1.09	0.978
R1-S	0.06	1.10	0.18	1.24	0.273
R1-PM	0.14	1.09	-0.16	1.24	0.810
C1-R1.PM	-4.30	5.02	0.83	6.02	0.037*

* Statistically significant difference.

DISCUSSION

Leveling is a phase of orthodontic treatment in which tooth movements can be complex and require careful planning.¹² In using this planning, orthodontists must select a bracket prescription, choose a wire sequence and determine the need for anchorage. A proper combination of these factors may allow goals to be achieved faster and with fewer complications.

Regarding wire sequence, no single alloy can boast all features necessary at all stages of orthodontic treatment.^{10,15,16,17} Orthodontists should be knowledgeable of all properties and clinical effects produced by the wires they use and select the best possible option for each treatment stage.

In this study, important clinical observations could be made about the wire sequences under study. In using Sequence 1, a statistically significant lingual movement occurred in the crown of the mandibular incisor (1.6 mm), although root position remained unchanged. The combination of these outcomes produced a lingual inclination of 4.3° in this tooth (Table 1). Sequence 2 caused the initial position of the mandibular incisor, both crown and root, to remain unchanged. Statistical comparisons revealed no significant difference between means at T_0 and T_1 (Table 2). The lingual inclination in the mandibular incisor after using Sequence 1 presented different characteristics in the two groups when these groups were compared (Table 3). In none of the sequences any vertical changes were noted in the position of mandibular incisors.

An interesting contribution that could be drawn from this study is the efficient control of tooth movement afforded by the sequences of stainless steel wires. The addition of passive torque to the mandibular incisor region allowed an adequate control of the buccolingual movement of these teeth, regardless of their initial inclination and bracket prescription. These results confirm the findings of Garcia⁴ and emphasize that tooth movement achieved with stainless steel wires can be better controlled, allowing

trained professionals to apply forces with a more balanced distribution in the anterior and posterior sectors and consequently achieve better anchorage control. Thus, one can selectively control tooth movement during orthodontic treatment.

Moreover, it was shown that reciprocal moments arising from the mutual interaction of heat-activated wires, especially rectangular wires (zero torque), interacting with the torques in the pre-adjusted brackets (-6°) did not allow full control over incisor movements since the information built into the orthodontic appliances prevailed. This action was complemented by rectangular stainless steel wires, also used with zero torque. Badran et al¹ also noted some uncontrolled tooth movement when using NiTi wires. In their experiment, the intercanine width tended to increase even when the transverse distance of the dental arches at the start of treatment was the same as the width of the orthodontic archwires. The deflection present in the anterior portion of the leveling archwires engaged in incisor brackets may have produced this expansion trend in intercanine width.

Considering the initial features of the cases in both groups, given the presence of a negative tooth arch discrepancy, one would expect mandibular incisors proclination, which failed to occur. This finding may be explained by the extraction of premolars and the use of lacebacks, which have proven effective in preventing the proclination of mandibular incisors during leveling.¹⁹

The time required for leveling was smaller using Sequence 1 (11 months) compared to Sequence 2 (21 months). However, one must consider that this investigation was conducted in a clinical research setting in postgraduate courses, and treatment time was accounted for by considering the dates of the radiographs. In Group 2, there was a greater delay in patient registration, extending treatment time. It is likely that, depending on the private practice, treatment length can be reduced, especially in Group 2. But in general, the use of heat-activated wires yielded outstanding time savings.

FINAL CONSIDERATIONS

Today, the use of archwires with shape memory without criteria and proper assessment of the benefits and issues arising from its use has become commonplace. The results of this study do not allow one to determine which wire sequence performed better. In fact, the major question is: What tooth movements are desired? If the bracket prescription, especially in terms of torque succeeds in producing desirable movements, then rectangular archwires with shape memory can be a very efficient tool. But if the idea is to avoid these movements, the goal cannot be achieved with these wires. The solutions to this stalemate would be to vary the prescription of the orthodontic appliance or individualize the torques using stainless steel wires. In contrast, the use of heat-activated archwires can be simpler and more convenient, reducing chair time and total treatment length. In this study, the time needed to complete leveling was shorter using Sequence 1.

Therefore, it is reasonable to assume that no single, optimal treatment method exists. All biomechanical variations under study showed advantages and disadvantages, which orthodontists should be aware of and consider in planning cases. Orthodontists should not generalize the wire sequence but rather select the best possible

option to meet the needs of each patient. Biological diversity is so extraordinary that it is bound to always require orthodontists' willingness to individualize orthodontic treatment in all its details.

The merit of well trained orthodontists lies not just in ensuring with their approach that a standardized, reliable method is implemented, but mainly in exploring the benefits and controlling the side effects of the various biomechanics employed, in their quest for the best treatment option to fulfill the unique needs of each patient.

CONCLUSIONS

Based on the methods applied and the results achieved in the present study, Sequence 2, which used stainless steel wires, yielded better mandibular incisor control with no changes in their initial positions, while Sequence 1, which used heat-activated wires, allowed the torques built into the bracket prescription to be expressed, leading to the lingual inclination of these teeth. Treatment time, however, was shorter using Sequence 1.

The biomechanical variations under study showed advantages and disadvantages, which orthodontists should be aware of and take into account in planning cases.

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Cephalometric analysis of the upper airways of Class III patients subjected to orthosurgical treatment

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Abstract

Objective: The aim of this study was to evaluate the effects of orthognathic surgery for mandibular setback – with and without combined maxillary surgery – on the upper airways (UA). **Methods:** Immediate lateral preoperative and postoperative cephalometric radiographs of 17 Class III patients were evaluated. Measurements of airway space (AS) diameter were taken in the sagittal plane in the hypopharyngeal and oropharyngeal regions, and changes in hyoid bone position were also recorded. Paired t-test and Pearson's coefficient were applied seeking for potential associations between skeletal and AS changes. **Results:** Significant AS reduction was noted in the hypopharyngeal region (mean= 3.10 mm, $p= 0.024$). The hyoid bone was displaced inferiorly and posteriorly, thereby reducing its distance to the anterior mandibular region. No quantitative correlation could be established between anteroposterior AS reduction and mandibular setback. However, there was a strong correlation between initial AS diameter and the amount of reduction observed in the hypopharynx, but only moderate correlation with the oropharynx. **Conclusions:** Mandibular setback can cause significant UA narrowing, especially in the inferior-most portion (hypopharynx). Therefore, special attention should be given to UA evaluation when formulating an orthosurgical treatment plan since the potential deleterious effects of these changes on functions of the patients should not be overlooked.

Keywords: Orthognathic surgery. Mandibular setback. Airways. Oropharynx. Hypopharynx.

INTRODUCTION

The upper airway (UA) – whose major component is the pharynx – consists of a tube that extends from the nostrils to the larynx (glottis).

This structure can be didactically divided into: Nasopharynx (superior-most region, related to the choanae), velopharynx (posterior region of the uvula), oropharynx (base of tongue) and

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hypopharynx (inferior-most region, posterior to the hyoid bone). The UA walls consist only of soft tissue and, therefore, is not supported by any rigid structure such as bone or cartilage. Thus, the mechanical support that ensures the continued opening of this structure in opposition to negative pressure during inhalation movements results from tension and contraction of the muscles that surround it.¹¹ This mechanism is due in large part to muscular insertions in the genial tubercles, which enable the mandible to be closely involved in the function and support of the tongue and related soft tissues. The genioglossus, geniohyoid and infrahyoid muscles are linked to the oropharynx and hypopharynx. The tongue muscles play an important role in maintaining airway opening, since they form the anterior wall of the pharynx in that segment.

Several procedures have been developed in the hope of increasing the pharyngeal airway space in patients with obstructive sleep apnea syndrome (OSAS). The goal would be to pull the tongue muscles anteriorly through mandibular advancement, thereby decreasing airway resistance to enhance air flow efficiency.¹⁴

On the other hand, one might question whether the opposite procedure, i.e., mandibular setback, could cause any reduction in pharyngeal airway space. This is a pertinent question since mandibular setback surgical technique is widely used in the treatment of Class III dentofacial deformities.

The effects of orthognathic surgery on the airways of healthy patients have not been fully explained in the literature, especially with regard to the risk of these patients developing OSAS in the postoperative period.

The purpose of this study was to assess and quantify, by means of cephalometric analysis, changes in the airways caused by orthognathic surgery involving mandibular setback, more specifically in regions directly related to the mandible, corresponding to the oropharynx and hypopharynx.

MATERIAL AND METHODS

Sample

Seventeen patients who had been subjected to orthodontic treatment in preparation for surgical correction of Class III dentoskeletal deformities were selected for this study. The surgeries were performed in the Department of Oromaxillofacial Surgery of the Pedro Ernesto State Hospital in 2006.

Six adult men and 11 adult women whose maxillofacial growth had already ceased were evaluated.

Surgical technique

Among the patients, 14 underwent combined orthognathic surgery for maxillary advancement and mandibular setback, whilst the remaining patients (3) were subjected to mandibular setback only. The surgical technique consisted of Le Fort I type maxillary osteotomy with rigid internal fixation. In performing mandibular setback, the technique of choice was bilateral vertical osteotomy with maxillomandibular fixation for a period of 2 to 3 weeks depending on the degree of occlusal stability.

Cephalometric analysis

Preoperative lateral cephalometric X-rays obtained up to 7 months prior to surgery as well as immediate postoperative radiographs taken up to one week after surgery were evaluated. Pre- and postoperative radiographs were obtained using the same device and in accordance with the standards of the lateral cephalometric technique.

All cephalograms were traced on acetate paper and all measurements were performed by the same examiner. Upper airway references were obtained according to the methodology advanced by Froberg et al,³ which can be seen in Figure 1.

Soft tissue measurements

1) Diameter of oropharyngeal airway (dark blue): Distance between the points determined by the intersection between the plane that extends from point B (the deepest point on the outer contour

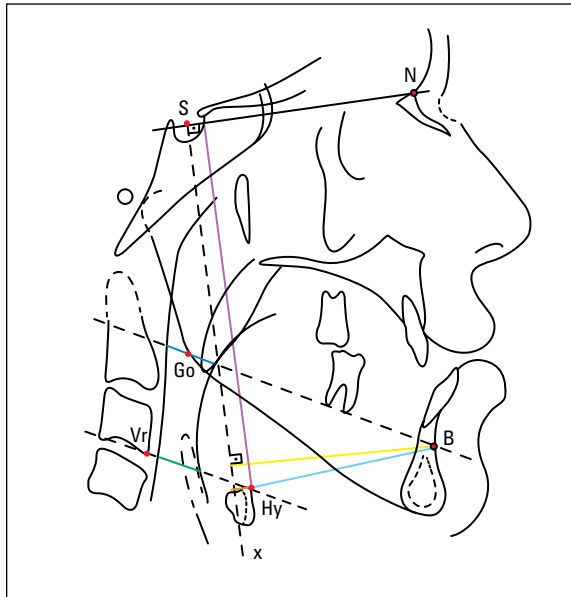


FIGURE 1 - Cephalometric landmarks.

of the mandibular alveolar process) to the gonion (Go - point determined by the intersection of the bisector of the angle formed by the lines tangent to the posterior and inferior borders of the mandible and the gonial angle), and the anterior and posterior walls of the pharynx. This measure intends to quantify the changes undergone by the oropharynx after surgery. Point B was selected as a reference as it constitutes the principal region of muscle insertion in the mandible, i.e., the genial tubercles.

2) Airway diameter in the hypopharynx region (green): Distance between the points defined by the intersection between the line extending from the most superoanterior point of the hyoid bone to the most anteroinferior point of the third cervical vertebra, and the anterior and posterior walls of the pharynx. This measure aims at quantifying the changes undergone by the hypopharynx after surgery.

Additional measures

3) Mandibular position (yellow): Measures the shortest distance between point B and a line perpendicular to SN (sella-nasion) passing through S (here called x). This measure discloses the amount of mandibular setback achieved through surgery.

4) SNA - Angle formed by the SN and NA lines (nasion-point A), where A is the deepest point on the contour of the premaxilla, which determines the degree of maxillary retrusion relative to the cranial base.

5) SNB - Angle formed between the SN and NB lines (nasion-point B), which expresses the degree of mandibular protrusion relative to the cranial base.

6) GoGn-SN - Angle determined by the intersection between the line joining the gonial (Go) and gnathion (Gn) points, and the SN line.

7) FMA - Angle determined by the intersection of the mandibular plane (line passing through the menton (Me) and tangent to the lower border of the mandible in the region of the gonial angle), with the Frankfort horizontal plane (junction of the Porium, Po, and orbitale, Or, points).

These last two angular measures (GoGn-SN and FMA) help to diagnose potential mandibular rotations in the vertical direction that can result from surgery, consequently inducing changes in the oropharyngeal reference plane.

8) Hy-SN (purple), the smallest distance between the most anterosuperior point on the body of the hyoid bone (Hy) and the SN line, revealing the vertical position of the hyoid bone relative to the cranial base.

9) Hy-x (orange), the smallest distance between Hy and line x, enabling the evaluation of the antero-posterior position of the hyoid bone.

10) Hy-B (light blue), distance between the Hy and point B, reflecting the relationship between the hyoid bone and the anterior region of the mandibular body.

RESULTS

Data were collected from the patients and all variables were used in the cephalometric analysis. Descriptive analysis including mean, standard deviation and minimum and maximum values measured on the preoperative and postoperative radiographs as well as the paired t-test are shown in Table 1. Some variables were compared with the purpose of establishing correlations between them, using Pearson's correlation coefficient (Table 2).

TABLE 1 - Descriptive statistics of cephalometric variables obtained from preoperative (T1) and postoperative (T2) radiographs.

Variable	X-ray	N	Mean	Standard Deviation	Minimum	Maximum				
SNA	T1	17	83.7647	3.56685	3.56685	89.50				
	T2	17	85.4412	3.96422	3.96422	91.00				
SNB	T1	17	86.2059	4.63026	4.63026	94.00				
	T2	17	82.1765	4.79890	4.79890	94.00				
ANB	T1	17	-2.4412	2.07577	2.07577	1.00				
	T2	17	3.2647	3.52277	3.52277	9.00				
GoGn-SN	T1	17	35.5882	5.70426	5.70426	46.00				
	T2	17	37.0882	6.17767	6.17767	55.00				
FMA	T1	17	26.6176	6.54916	6.54916	42.00				
	T2	17	28.8824	7.94223	7.94223	53.00				
Mandibular Position	T1	17	64.2647	7.47938	7.47938	76.00				
	T2	17	56.9412	7.70528	7.70528	71.00	X-ray 1	X-ray 2	t-test	p-value
Oropharyngeal Diameter	T1	17	16.8824	4.85583	4.85583	28.00				
	T2	17	15.9118	5.29515	5.29515	25.00	16.8824	15.9118	0.682	0.505
Hypopharyngeal Diameter	T1	17	13.0588	6.40772	6.40772	28.00	13.0588	9.6471	2.477	0.025*
	T2	17	9.6471	4.50959	4.50959	23.00				
Hy-SN	T1	17	113.0882	8.26747	8.26747	127.00	113.0882	117.3529	-3.707	0.002**
	T2	17	117.3529	8.69943	8.69943	132.50				
Hy-x line perp. SN	T1	17	9.1765	9.58505	9.58505	29.00	9.1765	7.0882	1.368	0.190
	T2	17	7.0882	9.87300	9.87300	26.00				
Hy-point B	T1	17	56.3235	7.16315	7.16315	67.50	56.3235	51.4412	2.805	0.013*
	T2	17	51.4412	6.49972	6.49972	65.00				

* Correlation at 0.05 significance level. ** Correlation at 0.01 significance level.

TABLE 2 - Pearson's correlation (r) between different variables.

		Change in oropharyngeal diameter	Change in hypopharyngeal diameter	Hy-SN	Hy-x	Hy-point B
Mandibular Setback	r	0.162	0.067	0.263	0.338	-0.261
	p	0.535	0.800	0.307	0.184	0.312
Initial airway space diameter	r	-0.526	-0.728			
	p	0.030*	0.001**			
Hy-SN	r	-0.389	-0.266			
	p	0.123	0.302			
Hy-x	r	0.224	0.102			
	p	0.388	0.697			
Hy-point B	r	-0.127	0.001			
	p	0.626	0.997			

* Correlation at 0.05 significance level. ** Correlation at 0.01 significance level.

DISCUSSION

In the cases analyzed in this study, the mandible experienced a mean setback of 7.32 mm after surgery. The impact on the airway space was evidenced by a mean reduction of 0.97 mm in the oropharynx and 3.41 mm in the hypopharynx. The initial mean diameters of these spaces were 16.88 mm and 13.05 mm, respectively.

This reduction was statistically significant only in the region of the hypopharynx ($P=0.025$), as shown by the paired t-test (Table 1). In a study⁸ where the smallest diameter in the posterior region of the tongue (which in most cases corresponds to the hypopharynx) was measured, the same result was found: Airway space reduction, in agreement with other authors.¹²

Despite this reduction in the hypopharynx, this study was unable to establish a significant quantitative correlation between this reduction and the mandibular setback, i.e., mandibular setback causes airway narrowing, but not proportionally. However, there was a strong correlation between the initial diameter and the amount of AS reduction in the hypopharynx ($r = -0.728$, $p < 0.01$). In the oropharyngeal region there was moderate correlation ($r = -0.526$, $p < 0.05$) between the initial diameter and the reduction observed in the airway after surgery. Thus, patients presenting extensive airway space in the preoperative period tend to experience greater AS reduction after mandibular setback surgery.

Because most patients underwent combined orthognathic surgery, one should take into account the influence of maxillary surgery on the final position of the mandible. This influence can be observed by a change in mandibular plane angulation, as assessed by measuring GoGn-SN. The correlation found between this measure and changes in the oropharynx ($r = 0.511$, $p < 0.05$) indicates a direct link between this space and mandibular rotation, i.e., when GoGn-SN increases (clockwise mandibular rotation) the diameter of the oropharynx is likely to increase as well.

This finding may explain the variability found in the behavior of oropharyngeal soft tissues, where it was found that 57% of patients who underwent mandibular setback associated with maxillary intervention showed an increase in oropharyngeal space. Otherwise, three patients who underwent mandibular setback alone experienced only a reduction in this space. Another explanation for this variation may be ascribed to a difficulty in standardizing tongue position during radiograph acquisition, since such position is very unstable and constantly changes in response to physiological movements.²

A study evaluating patients who underwent mandibular setback surgery alone found a reduction in airway space (in the mandibular plane) in all cases, establishing a correlation between these two variables ($r = 0.52$).⁵

Another significant finding was that the hyoid bone was displaced inferiorly (mean = 4.26 mm) in response to mandibular setback. Horizontally, bone movement varied with a slight prevalence of posterior displacement (2.08 mm), following the mandibular movement. Other authors^{4,7,12} also observed inferior and posterior displacement of the hyoid bone. In contrast, anterior displacement of this bone has also been reported.¹⁵

Reduction in the distance between the hyoid bone and the anterior mandible region (mean = 4.88 mm) was also a significant finding, which raised the question of how the suprahyoid musculature might behave. Changes in this muscle's tone are likely to take place over time to compensate for the decrease in this distance. The largest reduction found for this distance was 18 mm, corresponding to 27% of the original distance exhibited by this particular individual.

In this study, cephalometric radiographs were used to evaluate the upper airways. Although these X-rays provide a two-dimensional view of a three-dimensional structure, studies in the literature have shown adequate correlation between measurements obtained from lateral radiographs and CT scans, validating the former's use for this purpose.^{6,9}

Magnetic resonance evaluation of airway behavior after orthognathic surgery has shown no signs of edema in patients' airways in the immediate postoperative period.¹⁰ It is therefore safe to assert that the airway changes observed in this study were not masked by tissue edema but result in fact from movements induced by bone surgery.

This study focused on assessing changes in the immediate postoperative period. Other authors, however, followed their patients for longer periods: 3 months, 6 months, 1 year and up to three years. After one year, no significant tendency was found showing that airway soft tissues tend to return to their initial dimensions.⁵ Another study,⁷ which used computed tomography, also demonstrated this same result. A two-year or longer follow-up actually suggests that changes occur in the airways over time after mandibular setback surgery.¹³ Moreover, some authors argue that the hyoid bone tends to return to its original position, probably because mandible position tends to relapse forward and upward even though the hyoid bone does not quite extend as far as the mandible.⁴

Although there are many studies on this subject in the literature, any comparison between them is complicated by the use of a wide range

of different methodologies, which are still rather limited due to the nature of airway tissues and their dynamic structure. Further studies are warranted to clinically evaluate the impact of changes observed in cephalometric radiographs. Are such changes sufficient to cause dysfunction or are they within the scope of physiological limits? The answer to this question requires that patients be interviewed for possible symptoms of discomfort, breathing or swallowing difficulties, snoring, apnea or other symptoms that might exert a genuine impact on the health of these individuals.

CONCLUSIONS

Mandibular setback orthognathic surgery for treatment of cases with Class III facial deformity can lead to significant upper airway narrowing, especially in the lower portion, which comprises the hypopharynx (3.41 mm). Careful attention should therefore be given to the evaluation of this area in lateral view cephalometric radiographs during the stage of orthosurgical treatment planning, as potential deleterious effects, not only as a result of this reduction but also due to other alterations in crucial patient functions, should not be overlooked.

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Stress distribution in a photoelastic model resulting from intrusion of mandibular incisors using Ricketts utility arch

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Abstract

Objective: This study aimed to investigate stress distribution in a photoelastic model generated by Ricketts Utility Arch (RUA), also known as Ricketts base arch, for intrusion of mandibular incisors. Stresses in the root thirds of each incisor were compared and the existence of differences in the concentration of stresses between the incisors was also examined. **Methods:** Fifteen intrusion RUAs were fabricated. Activation force was set at 50 gf in the midline region. The photoelastic model was observed in a circular polariscope in dark field configuration and photographed. Frontal view photographs were analyzed and fringe orders recorded in each region. Weighted Kappa analysis was used to identify method repeatability. Comparison between stresses was performed by Kruskal-Wallis test and complemented by Dunn's test at 5% alpha level. **Results and Conclusions:** Results showed that the major stress magnitudes were found in cervical regions. By comparing fringe orders between teeth the major stress magnitudes were found to be in the central incisors. Cervical regions and central incisors may therefore be more prone to resorption given their greater stresses.

Keywords: Photoelasticity. Intrusion. Biomechanics. Root resorption.

INTRODUCTION

Ricketts utility arch (RUA), also known as base arch, has been described as a resource to promote the intrusion of incisors in correcting overbite, mainly in the Bioprogressive technique.^{17,21} RUA effectiveness in obtaining real incisor intrusion has been confirmed.^{1,18} There have been reports,

however, that intrusion is but one contributing factor among others, such as incisor proclination and molar extrusion, which occur during overbite correction using RUA.

RUAs are usually made out of blue temper chromium-cobalt alloy (Elgiloy®), whose properties resemble those of steel, but with increased formability.

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Elgiloy composition comprises 40% cobalt, 20% chromium, 15% nickel, 15.8% iron, 7% molybdenum, 2% manganese, 0.16% carbon and 0.04% beryllium.¹³ After RUA fabrication heat treatment is not recommended as it would lead to increased force generation by the arch.^{16,17}

RUAs are double binary intrusion arches featuring a greater moment in molars due to a caudal angle, and another moment in the anterior region, caused by lingual torque in the incisors. Given that the moments occur in the same direction, balance forces are summed. However, if anterior torque is applied buccally, moment will be created in opposition to the molar. Therefore, since molar and incisor moments will be in opposite directions, intrusion force will be diminished in the anterior region. If anterior buccal torque moment is greater than molar moment, incisors may undergo extrusion.³

Stress distribution resulting from intrusion RUAs was verified by another study,¹⁹ which identified the formation of photoelastic fringes around incisor roots and uniform results between teeth. Considering that the aforementioned study made use of a 4x2 system and a stainless steel RUA, the authors of this study decided to examine the stresses produced by an intrusion RUA fabricated with chromium-cobalt alloy, with the aid of posterior anchorage, using a rectangular sectional archwire.

This study analyzed stress distribution in a photoelastic model resulting from an intrusion RUA, compared stress magnitudes in root third regions and checked stress uniformity in the four mandibular incisors.

MATERIAL AND METHODS

Firstly, brackets (Ovation/Dentsply GAC International, New York, USA) were bonded with Super Bonder glue (Loctite, Barueri, Brazil) to artificial teeth (B2-306/Kilgore, Nissin, Kilgore International, Michigan, USA), and bands (Roth prescription / "A" company - San Diego, USA) were cemented to molars.

To simulate mandibular incisor overeruption, a rectangular 0.021 x 0.025-in stainless steel archwire was inserted with a pronounced 4 mm curve of Spee in the premolar region, in a method relatively similar to that of a previous study.⁷ A 0.021 x 0.025-in cross-section wire was used to ensure a reduction in the play of the wire in the bracket/tube slots.

A metal strip was shaped like a horseshoe and adapted onto a caulked glass plate so as to allow liquid wax #7 to be poured with the same width along the entire arch. This procedure was performed due to the fact that model thickness has a bearing on fringe formation:

Fringe order = δ/λ , where:

» δ = relative delay,

» λ = wave length.

And relative delay = $\delta = Kt(\epsilon_1 - \epsilon_2) = (n_1 - n_2)t$, where:

» K = optical stress constant,

» $\epsilon_1 - \epsilon_2$ = difference between the principal strains,

» $n_1 - n_2$ = difference between refraction indices (birefringence),

» t = thickness of the material.

The set was bonded with Super Bonder glue inside a plastic pot. Blue silicone rubber (ASB-10 Blue/Polipox, São Paulo, Brazil) (300 ml) was mixed slowly with the catalyst (21 ml) to prevent the inclusion of air bubbles, and poured until the set was completely covered.

After 48 hours the wax was removed with hot water and detergent. To complete wax removal, a product called Remox (Vipi, Pirassununga, Brazil) was used. The cast was then washed and dried with compressed air.

GII flexible set (Polipox, São Paulo, Brazil), consisting of resin and hardener, was mixed in the ratios recommended by the manufacturer (100:40 ml) in a Becker pot with the aid of a glass rod for 2 minutes. To eliminate air bubbles, the mixture stood for 15 minutes inside a vacuum chamber at -700 mmHg. The resin was poured into the cast slowly

with the aid of a glass rod, once again placed in the vacuum chamber for 30 minutes and allowed to rest for 24 hours.

After 72 hours the specimen was removed from the cast. It was, therefore, necessary to cut the cast in the cervical region of the crowns. After fabrication of a photoelastic pattern, the arch was removed and a silicone impression of the crowns with brackets on was performed to serve as guidance in rebonding, in case any items fell off during the experiment.

Fifteen RUAs were fabricated, contoured with the help of diagrams (Tru arch form, "A" Company, San Diego, USA) in the largest size of the mandibular arch. In Ricketts mechanics, RUAs are usually made of Blue Elgiloy® 0.016 x 0.016-in wire (Rocky Mountain, Denver, USA) since in the Bioprogressive technique bracket slot dimensions are 0.018 x 0.030-in.

Blue 0.016 x 0.022-in Elgiloy® wires (Rocky Mountain, Denver, USA) were utilized, since the slots of the brackets used in this study (Ovation/Dentsply GAC International, Bohemia, NY, USA) were 0.022 x 0.028-in. Brackets with 0.019 x 0.019-in slots could have been used. Instead, however, since the author of another study¹⁹ had used 0.016 x 0.022-in slot brackets, using the same wire size would ultimately facilitate a comparison between results.

The archwire form had 45° distal tipping, 15° distolingual rotation, 30° posterolingual torque, vertical deviation on the mesial side of the first molar tube and on the distal side of the lateral incisor,¹⁶ as well as anterior lingual torque.^{3,17}

The steel 0.021 x 0.025-in archwire used to simulate the malocclusion was cut into two posterior sections (from distal side of second molars to mesial side of first premolars) and one anterior section (from distal right of lateral incisor to distal side of left lateral). The posterior sections were kept as posterior anchorage.

A tension gauge (250/Correx, Haag-Streit AG, Koeniz, Switzerland) was used to measure the

forces in the intrusion arches. Gradation begins at 25gf and ends at 250gf. Initially, all intrusion arches should generate 50gf. Those that failed to exhibit such force had their caudal angles adjusted so that the force would reach 50gf.

After arch insertion, the model was studied in a circular polariscope (Eikonal Instrumentos Ópticos, São Paulo, Brazil) (Fig 1) set up with the following elements: Light source, light diffuser, polarizer, quarter wave plate, photoelastic pattern, quarter wave plate and analyzer. A camera (D70 Nikon, Melville, NY, USA) was mounted on a tripod and positioned in front of the analyzer. The photoelastic pattern was embedded in a stress-free acrylic container containing mineral oil and placed on a turntable with markings to allow proper repositioning of the model.

The cubic container, built from virgin acrylic, was previously observed in the polariscope to ascertain the absence of residual stress, which might interfere with the observation of fringes in the model. After the absence of stress in the container had been verified, it was filled with mineral oil as it favors the observation of fringes in complex models. For each arch replacement, removal of model from the container was carried out with the examiner wearing gloves to avoid oil contamination.



FIGURE 1 - Circular polariscope used in experiment (Eikonal Instrumentos Ópticos, São Paulo, Brazil).

After insertion of each arch, photographs were taken in frontal view. The photographs were taken by following certain criteria so that any comparisons between them would not be affected by other variables.

During the experiment: (a) The same distance was kept between all polariscope components as they remained in position until the end of the experiment, (b) The angle between the photoelastic model and the camera lens was maintained, as well as (c) The aperture ($f=8$), speed ($v=1/400s$) and framework (0.45) of the camera.

In order for the model to be repositioned in the same location after insertion of every new arch, pre-existing markings on the turntable were positioned in such a way that the mesial surfaces of the first molars were made to coincide with the horizontal line while the midline coincided with the center line perpendicular to the aforementioned line.

The photographs were always taken at the same location while maintaining the same lighting conditions in the environment. The digital photographs were exported to a computer and analyzed using the zoom feature. Considering Table 1, fringe orders were recorded for all images and recorded in spreadsheets separated by tooth (42, 41, 31 and 32), apical, middle and cervical root thirds, mesial and distal surfaces.

Figure 2 shows one of the photographs of stresses generated by the arch and analyzed in the experiment.

Statistical method

In order to assess intraobserver agreement (repeatability) of the method, five photographs were selected and all areas reassessed with a one-week interval. The values of fringe orders arising from such assessment were used along with the first analysis to calculate weighted Kappa statistics. Calculation of weighted Kappa coefficient was performed using Microsoft Excel spreadsheets.

To compare the fringe orders between root thirds the Kruskal-Wallis test was employed. A 5%

Color	Relative delay (Nm)	Fringe order (δ/λ)
Black	0	0
Grey	160	0.28
White	260	0.45
Light yellow	350	0.6
Orange	460	0.79
Intense red	520	0.9
Red-blue transition	577	1
Intense blue	620	1.06
Blue-green	700	1.2
Green-yellow	800	1.38
Orange	940	1.62
Pinkish red	1050	1.81
Red-green transition	1150	2
Green	1350	2.33
Green-yellow	1450	2.5
Red	1550	2.67
Red-green transition	1730	3
Green	1800	3.1
Pink	2100	3.6
Pink-green transition	2300	4
Green	2400	4.13

TABLE 1 - Sequence of colors produced in polariscope with white light in a dark field configuration. Sources: ASTM D4093-95 (re-approved 2001) and www.vishay.com.

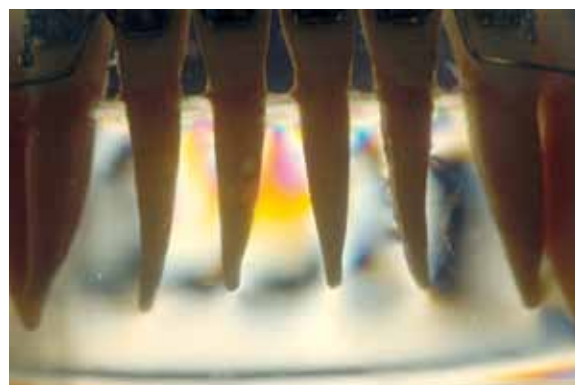


FIGURE 2 - One of fifteen photographs of stresses caused by RUAs and analyzed in this experiment.

significance level was adopted. The hypotheses under test were:

» Null hypothesis: Fringe orders in the areas of root thirds had the same distribution.

» Alternative hypothesis: At least two fringe orders in the areas of root thirds exhibited different distributions.

To compare the fringe orders between root thirds the Kruskal-Wallis test was also employed.

» Null hypothesis: Fringe orders in the teeth being compared had the same distribution.

» Alternative hypothesis: At least two fringe orders in the teeth being compared exhibited different distributions.

The Kruskal-Wallis and Dunn tests were performed using SigmaStat statistical software while Minitab statistical software was used to identify the mean rankings.

RESULTS

Weighted Kappa values indicated agreement between the first and second examinations in each region in each patient, ranging from substantial to almost perfect (Cdi=0.61 to 0.82, Cme= 0.73 to 0.86; Mdi=0.61 to 1, Mme=0.70 to 1, and Api=0.61 to 1).

Figure 3 identifies the descriptive statistics consisting of median, first quartile and third quartile, maximum and minimum fringe order values resulting from the use of RUAs in the following regions: Cervicodistal (Cdi), cervicomesial (Cme), mid-distal (Mdi), mid-mesial (Mme) and apical (A) of mandibular right lateral (42), right central (41), left central (31) and left lateral (32) incisors.

Table 2 depicts the results of the Kruskal-Wallis and Dunn tests for fringe orders between the cervical, middle and apical regions, and between the teeth, using RUAs.

Figure 4 illustrates percentages of the major stress magnitudes related to the statistically significant differences found between root thirds, resulting from intrusion RUAs.

When using RUAs, the major stress magnitudes

were observed in cervical regions, with 56.6% of differences identified on the mesial and distal surfaces and 34.8% on the distal surfaces, and 4.3% in the middle third of mesial surfaces and 4.3% in the apical third.

Figure 5 illustrates the percentages of the major stress magnitudes related to the statistically significant differences found between the teeth for each intrusion archwire.

By comparing fringe orders between the teeth in each root third, the major stress magnitudes were observed in central incisors, with 45.4% of the differences identified in the left central incisor and 36.4% in the right central incisor, and 9.1% in each lateral incisor.

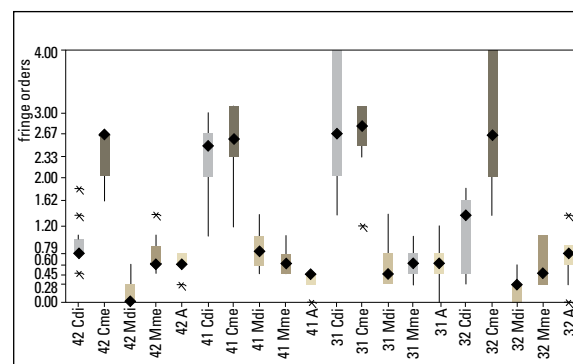


FIGURE 3 - Descriptive statistics for the fringe orders from the use of the Ricketts Base Arch.

TABLE 2 - Results of Kruskal-Wallis and Dunn tests for fringe orders in the cervical, middle and apical regions using Ricketts mechanics.

Teeth	Cdi Median	Cme Median	Mdi Median	Mme Median	Apical Median
42	^{A,B} 0.79 ^b	^A 2.67 ^a	^C 0.0 ^b	^B 0.6 ^a	^{B,C} 0.6 ^a
41	^A 2.5 ^a	^A 2.67 ^a	^B 0.79 ^a	^{B,C} 0.6 ^a	^C 0.45 ^b
31	^A 2.67 ^a	^A 2.67 ^a	^B 0.45 ^a	^B 0.6 ^a	^B 0.6 ^a
32	^B 1.2 ^b	^A 2.67 ^a	^C 0.28 ^b	^{B,C} 0.45 ^a	^{B,C} 0.79 ^a

Capital letters (A, B, C) differ horizontally (difference between regions in each tooth root), and lowercase letters (a, b) differ vertically (difference between teeth in each root region).

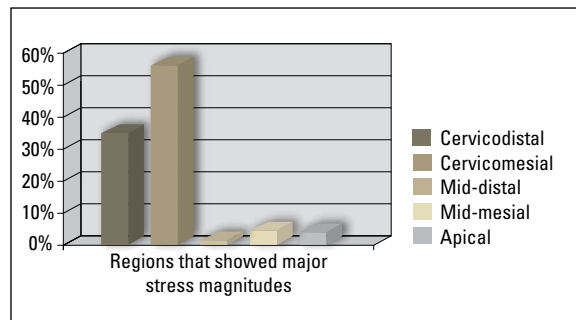


FIGURE 4 - Percentages of major stress magnitudes related to the statistical differences found between the apical, middle and cervical regions, mesial and distal surfaces.

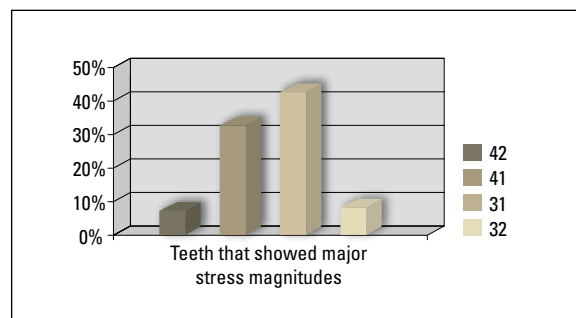


FIGURE 5 - Percentage of major stress magnitudes related to statistical differences found between teeth.

DISCUSSION

Although the literature reports¹⁹ a study of fifteen intrusion arches using the same pattern in gelatin, in this study the use of a composition of gelatin/glycerin/water was rejected after a pilot study was performed because when replacing the arches the integrity of the photoelastic material became gradually impaired. It was decided, therefore, that photoelastic resin would be used instead, but with an elastic modulus similar to that of gelatin, so that the light forces delivered by the intrusion arches would be capable of generating internal stresses and thus be visible to photoelastic analysis.

The use of gelatin appears to be quite convenient in research where, in addition to force distribution, tooth movement is also investigated, since gelatin exhibits enough creep (strain undergone by a given material over time when subjected to constant load or voltage) to accomplish tooth movement.^{2,7}

Any comparison between the results achieved in this study and those found in the literature would be quite limited given the scarcity of studies that assess intrusive mechanics using photoelasticity and the peculiarities inherent in the methodology.

There are reports,¹⁹ for example, on the analysis of stress distribution of RUAs in the mandibular arch using the same wire cross-section size (0.016 x 0.022-in) and amount of force (50gf) employed in this study. However, studies differ in several aspects, among them the fact that the above study¹⁹ used stainless steel instead of chromium-cobalt alloy, did not use posterior anchorage, used different photoelastic materials (gelatin, as opposed to resin, which was used in the present study) as well as the polariscopes (plane polariscope in the aforementioned study¹⁹ vs. circular polariscope in this study) and the manner in which fringes were analyzed. Although any comparison between the results can be regarded as mere speculation, the homogeneity of stresses found between the incisors in the above study¹⁹ differs from the present study, which identified greater stresses in the distocervical and mid-distal surfaces of central incisors, whereas in the apical region results indicated greater stresses in lateral incisors. These results are probably related to the moment generated by the force as it dissipated from the distal side to the midline.

In this study, the root area of the left lateral incisor used in the experiment appears to be smaller than the right lateral, which might have influenced stress distribution. There were, however, no significant differences between the fringe orders of these teeth.

Root anatomy affects stress distribution and the key factor in determining force distribution is the apical area. Those teeth that taper from cervical to apical feature a lateral compression that influences the force magnitude required to produce the same strain in cylindrical and tapered roots from apical to cervical.⁶

Root structure configuration and direction of force application are straightly related to stress distribution. Intrusive forces delivered along the axis induce the formation of symmetrical fringes at the apex, and tend to be more intense in teeth with smaller root areas.¹⁴

The fact that RUAs generated stresses in the apical region suggests that forces resulting from this type of arch show an axial direction. This result is consistent with a clinical¹⁸ trial that compared various intrusive mechanics and identified greater effectiveness in the intrusion of incisors with the aid of RUAs and Burstone intrusion arches.

Clinical result extrapolation should be considered with caution since the photoelastic method does not accurately reproduce the role of the periodontal ligament.⁶ Natural periodontium fibers are oblique and thus prevent compression of the apex so that the distribution of axial forces is uniform along the root walls.^{6,10} Apparently, the tensile force in these oblique fibers induces the formation of inclined bone spicules.²² However, other authors⁶ argue that root form influences stimulus type. In tapered roots, pressure stimulus occurs even in the presence of axial forces while in cylindrical roots the physiological movement of intrusion can be supported by periodontal ligament fibers, which transform into tensile forces in the alveolar wall.

It has been argued that intrusive forces may be absorbed mostly by the cervical and middle areas when applied to tapered tooth roots covered with photoelastic material.⁸

Studies^{20,23} using finite element identified in the cervical region a higher stress concentration when applying intrusive forces, regardless of root form.²⁰ Nevertheless, another study¹¹ with finite

element found higher levels of pressure in the subapical and apical regions.

Intrusion is just one factor in the reduction of overbite using RUAs,¹² as no correlation was found between amount of intrusion and reduced overbite (Kendall's tau = 0.14), whereas correlation was found between overbite and increased lower anterior facial height (Kendall's tau = 0.46) and molar extrusion (Kendall's tau = 0.32). In the aforementioned study no stabilizing segment was used in the posterior sector, so probably there was a greater extrusion of mandibular molars with a consequent increase in lower anterior facial height.

In this study a 0.021 x 0.025-in stabilizing arch was maintained in the posterior sector of all arches. Thus, the effects of the arches were more restricted to the anterior teeth.

Stresses generated by RUAs are the result not only of an intrusion activation force of 50gf, but also of an anterior lingual torque placed in the arch since the presence of anterior lingual torque also tends to increase intrusion forces.^{3,4,5} Moreover, the greater stresses in the mesial middle third compared to the distal middle third, found in the present study, could probably be explained⁵ by the fact that the presence of the wire inside the incisor brackets could displace the roots mesially. Dake and Sinclair⁹, in a clinical study, observed a "fan" movement in the lower incisors, in the group using RUAs.

It should also be stressed that the arch was built from chromium-cobalt alloy (blue Elgiloy), which features a high elasticity modulus, similar to stainless steel,¹⁵ with a high load/deflection ratio, thus tending to release high loads for short periods. In addition, the system of forces in RUAs is statically indeterminate, which therefore renders the calculation of acting forces and moments a complex task.

The methodology employed in this study allowed the identification of fringe orders in root thirds and enabled statistical analysis. Fringe interpretation is qualitatively performed in one single specimen.

The results found in this study allowed the authors to visualize and understand the effects of the use of RUAs on the lower incisors as well as identify the teeth and areas of greater stress concentration and therefore more prone to resorption. Regarding resorption, even more important than force magnitude and type is the manner in which such force is distributed around the root.⁸ Given the originality of this study, however, results should be viewed with caution while further investigation is warranted to confirm reproducibility. Future studies will likely contribute to an analysis of other con-

founding factors related to incisor intrusion, such as the influence of lingual torque, bracket slot angulation, wire thickness and a comparison between different intrusive mechanics.

CONCLUSIONS

Considering the conditions under which the study was conducted, it can be concluded that:

- 1) Results showed that the highest stress magnitudes were observed in cervical regions.
- 2) The teeth with the highest stress concentrations were central incisors, particularly their distal surfaces, cervical and median regions.

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Clinical and radiographic guidelines to predict pubertal growth spurt

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Abstract

Objective: The aim of this paper is to emphasize the organization of the information available in exams and along the orthodontics treatment of growing individuals, which are used as guidance to predict the pubertal growth spurt. **Conclusion:** Such information provide opportunities to increment the diagnosis and prognosis of these cases and in making planning decisions, treatment evolution and the retention phase, mainly for those patients presenting malocclusions associated to skeletal disharmonies.

Keywords: Growth. Prediction. Diagnosis. Prognosis. Malocclusion.

INTRODUCTION

The use of clinical and radiographic guidelines to predict a patient's skeletal maturation is a routine practice for healthcare workers that adopt an integrated approach to examinations. Using these findings, the pubertal or adolescent growth spurt may be assessed to define whether it is imminent, present or complete.^{4,28}

This type of knowledge is useful when patients are referred to orthodontic treatment, particularly because certain stages of pubertal growth spurt may benefit the treatment of some types of malocclusion associated with skeletal disorders.¹⁷

However, the detection of pubertal growth spurt in each individual is complicated because it occurs at different chronological ages.¹⁸ Its prediction at least one year in advance may be essential if the purpose is to take advantage of it during orthodontic treatment.^{17,20,24}

The direct clinical application of this prediction,

when made before orthodontic treatment, complements orthodontic diagnosis, planning and prognosis,^{2,23} particularly because growth increments are maximized during this phase.² Therefore, in specific cases, less tooth movement may be required, and growth may be an ally; under other clinical conditions, tooth movement will have a predominant role in treatment results,²⁰ and growth should be controlled or even redirected, depending on whether its pattern is favorable or unfavorable.²⁴

All individuals undergo a pubertal growth spurt, but there are differences in onset, duration, velocity and amount of growth.^{10,18,29} This life phase is characterized by growth acceleration and achievement of velocity peak, which then slows down until adulthood is reached.²⁹

This paper describes methods to predict the adolescent growth spurt focusing on the clinical applications of this knowledge and the variability of the characteristics described.

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LITERATURE REVIEW

Along the history of orthodontics, authors and clinicians have been interested in craniofacial growth and bone development.

The regular assessment of physical maturation stages in adolescence provides extra information for treatment planning and progression and for decisions about retention type and duration after orthodontic treatment. Such decisions should be based on the evaluation of occlusal stability after treatment, which may be completed before the end of the growth spurt peak.^{2,23,25}

Maturation may be described as the development process that completes physical growth, and its current level or stage can be measured and graphically represented in simple ways.² Growth potential, in contrast, is defined as the increase that may occur between current and final bone size, and this information is more difficult to obtain.²⁵

The interpretation of some clinical and radiographic signs as a whole may provide an evaluation of an individual's level of maturation.⁶ Among these physiological parameters are chronological, skeletal and dental ages, sex, sexual development, genetic factors^{2,6} and ethnicity.^{12,25}

Chronological age

Mental maturity, physical capacity, height, weight and number of teeth in the mouth are usually estimated according to chronological age. However, there are differences between individuals, even in groups of people with common traits and the same sex and age, particularly during adolescence, a phase when physiological differences become more evident.^{2,15} Other variables, such as nutritional and endocrine status and certain metabolic diseases, affect adolescent development.^{5,9,14}

Chronological age alone may not be used as a valid parameter to estimate growth velocity or skeletal maturity and is not, therefore, a relevant diagnostic element for treatment when used alone.^{9,10}

Skeletal age

The evaluation of skeletal age using radiographs is widely used in healthcare to predict the phase of pubertal growth and to estimate growth velocity and remaining growth (growth potential).

The wrist and hand radiograph provides the best indication of skeletal maturation, particularly because it provides visualization of several ossification points in a small area.¹⁶ Some methods have been developed to estimate skeletal age, such as those described by Greulich and Pyle (GP), Tanner et al (TW3), and Eklöf and Ringertz (ER). The GP method uses an atlas that contains a sequence of radiographs of the hand and wrist obtained every six months of healthy American boys and girls with similar characteristics. For each radiograph, a chronological age corresponding to the skeletal age is assigned.¹⁴ The TW3 method also compares radiographic reference standards of skeletal maturation of white children of the same sex and similar ages to define skeletal age.^{10,16} It assesses specific ossification centers in the hand and wrist (radius, ulna, metacarpal bones and specific phalanges) and assigns values to estimate skeletal age.¹⁶ The ER method calculates skeletal age using ten linear measures of certain bones and comparing them with pre-established values.⁸

For those not familiar with the anatomy and sequence of calcifications of the carpal and finger bones,¹⁴ authors have simplified the clinical application of some reliable bone maturation guidelines, such as the appearance of the sesamoid ulnar bone in the metacarpophalangeal joint of the first finger (thumb) and the capping between epiphysis and diaphysis of the proximal and middle phalanges of the second (index) and the third (middle) fingers.³⁰ For that purpose, the use of periapical radiographic films is an excellent option.^{3,30}

All the data about growth spurt and body height are useful because the curves of both

maximum facial pubertal growth and body height are strictly associated in the same individual.^{10,29}

Moreover, the close association between maximum body and facial growth and ulnar sesamoid ossification was longitudinally studied and confirmed for boys^{1,4} and girls.^{4,7}

The conclusions drawn from those studies have direct clinical applications because they confirm differences between sexes regarding onset, duration and intensity of the maximum pubertal growth spurt.

However, some studies in the literature criticize the fact that chronological ages are assigned to certain skeletal development phases based on conclusions whose reliability is uncertain.⁹ Moreover, the possibility of exposing patients to X-rays several times is reason for concern.²³

The wrist and hand radiograph should be seen as a complement, rather than a replacement, to other valid methods to evaluate a child's physical condition.¹⁴

A practical alternative is the lateral extraoral radiograph, usually requested for orthodontic diagnosis and which may also be used for growth predictions by evaluating bones of the spinal column¹⁹ and the development of the frontal sinuses.²³ The end of the spurt phase peak in adolescent boys may be identified by the development of the frontal sinuses.²³

Recent attempts to obtain more reliable data to estimate growth potential have been made using mathematical and computational methods that are, however, still based on hand and wrist radiographic guidelines²⁵ and the visualization of the cervical column on lateral extraoral radiographs.¹⁹

However, body, maxillary and specially mandibular growth are not stagnant at the end of the maximum growth spurt, even in patients with Angle Class II or Class III malocclusion, which affects the prognosis of orthodontic treatment.^{13,22}

Lateral extraoral radiographs may also be used to predict the resulting craniofacial growth

when studied using one or more of the methods available: Longitudinal, metric or structural. It is not enough to estimate the amount of growth, but also the direction towards which growth will be more intense.²⁰

Dental age

Studies in the literature, such as the ones conducted by Demirjian et al⁶ and Nolla²¹, assigned scores to define the several calcification and mineralization stages of permanent teeth.

Despite their practicality and easy clinical application,⁶ general tooth development indices are not reliable in predicting an individual's skeletal maturation stage.^{4,5,7,10}

Some authors tried to correlate certain permanent teeth, such as mandibular canines,^{4,5,6,26,27} mandibular second premolars²⁸ and third molars,¹¹ with skeletal age.

The development of mandibular canines is more strictly associated with height velocity peak than other teeth.^{4,5,6,26,27} There is a strong positive correlation between root mineralization of mandibular canines — before apical closure, usually at the same time as it erupts into the oral cavity — and the onset of pubertal growth spurt, at a degree similar to that of the sesamoid bone calcification. When the dental apex is closed, the finger epiphyses and diaphyses are usually already fused, and growth spurt peak has already been achieved.^{4,5}

The degree of calcification of mandibular second premolars and third molars should not be used¹¹ as radiographic indices of pubertal growth spurt in boys and girls.^{11,28}

Sex

Girls usually mature earlier, with a mean difference of two years for the onset of pubertal growth spurt.^{2,30} Boys not only reach maturation later, but the magnitude of their growth velocity peak is also considerably greater than that of girls.²

In a similar way, there are remarkable differences in the distribution of tooth calcification and mineralization phases between sexes.^{4,21} Girls usually begin and end their dental development earlier than boys.²¹

Clinically, these differences suggest the need to start orthodontic treatment earlier in girls than in boys.²

Sexual maturation

Skeletal maturation, maybe the most common index in clinical routine, is believed to be associated with sexual and physical maturation.⁷

Profound hormonal changes are seen during puberty.² Androgenic secretions in men are composed of testicular and adrenal secretions, whereas in women they are primarily adrenal. These hormones have metabolic effects, promote bone growth and govern the development of the primary and secondary sexual traits.⁵

During adolescence, the reproductive system undergoes major development, and secondary sexual traits appear. In boys, the voice changes, and the mustache and beard grow, frequently during the beginning of the pubertal growth spurt. The appearance of pubic and axillary hairs, together with the growth of external genitals, reflects the progressive stages of male sexual maturation. These changes are followed or preceded by the pubertal growth peak.²

In girls, the appearance of pubic and axillary hairs and the growth of breasts indicate the development of the reproductive system, and there is a constant association between menarche (first menstruation) and the time at which pubertal growth peak occurs.² Height velocity peak is reached about one year before menarche, and is an excellent guideline to measure the sexual maturation of girls.^{2,7,14}

Girls with greater skeletal ages also have an earlier menarche and usually grow more after menarche than those that have a later menarche.²

Skeletal maturation and the appearance of

the ulnar sesamoid bone are associated,^{4,5,7} and the correlations between their appearance and menarche are also consistently strong.⁷

Ethnicity

Comparative studies with populations from different ethnic groups have been conducted.^{7,12,19,25} A longitudinal study between groups of African-American, Hispanic and Asian-American adolescents of both sexes collected hand and wrist radiographs, lateral cephalometric radiographs and measurements of body height to compare their data with those for white Americans.⁹ Significant differences were found in onset, duration, intensity and end of pubertal growth spurt in the sample of 922 adolescents.¹²

Marked ethnic differences have also been found in the comparison of tooth calcification patterns.⁴ Signs of variation in bone shape and ossification rate were found in comparisons between white and Japanese individuals.^{19,25}

Genetic factors

Genetic factors should be evaluated when predicting pubertal growth spurt.^{2,6} The number and size of teeth are genetically determined. Shape, function and skeletal growth are also affected by genetic factors, but may also be changed by environmental factors.^{2,6}

DISCUSSION

The complexity of data in general dentistry literature about the prediction and clinical use of the pubertal growth spurt may be one of the difficulties to use maturation guidelines in dental diagnoses.

As seen before, there is a positive correlation between physical and facial pubertal growth spurt.^{1,4} The treatment of some orthodontic problems may be facilitated or complicated by the patient's growth potential and type. Therefore, it is useful to identify physical maturation indices when examining children and adolescents that

present with malocclusion,^{2,23} particularly when associated with skeletal disorders.²⁰ Growth rates may also affect the choice of timing and treatment type for cases that should be treated only with orthodontic procedures and for those that may actually benefit from complementary orthognathic surgery.²⁰

The prediction of facial growth spurt peak is more reliable if based on knowledge associated with maturation guidelines.^{2,23} Therefore, during clinical examination and history taking, the observation and recording of some simple information may enrich diagnoses and guide general clinicians and pediatric dentists to refer patients to orthodontic treatment. Such information may also affect treatment plans established by orthodontists.^{2,23} As a consequence, questions are raised and findings about chronological age should be taken into consideration.^{2,6} The appearance of some secondary sexual traits,² such as the menarche in girls;^{2,7,14} height records for the patients, parents and older siblings^{1,2,14} and the presence of permanent mandibular canines in the oral cavity^{4,5,6,26,27} should be analyzed and checked at each visit, and the information collected may be used for the prediction of pubertal growth spurt.

Routine radiographs in dental clinic, such as panoramic and periapical films, may be used to define the stage of mandibular canine calcification and mineralization, a reliable guideline to

define adolescent growth spurt stages.^{4,5,6,26,27} For further investigation and confirmation, periapical radiographs, radiographs of some hand bones^{3,30} or even hand and wrist radiographs^{1,4,7,14} may be requested and used for longitudinal comparisons of the same patient.⁹

Moreover, genetic factors,^{2,6} as well as differences between sexes and ethnic group,^{4,7,12,19,25} may be associated with the onset, duration, intensity and end of the pubertal growth spurt. Therefore, they may affect the time and way that information about growth potential should be used in orthodontic treatments, which should also include additional care in preventing relapses.

This knowledge and its applications should be kept in mind when making decisions about treatment. Data may be retrieved from treatment routine practices, and they should be used timely as guidelines.

CONCLUSION

The addition of clinical and radiographic indicators of physical maturation to the dental record of children and adolescents may be simple, and findings may be useful for referral, diagnosis, planning and prognosis of the treatment of certain types of malocclusion.

The inclusion of such information in routine examinations may also provide a general overview of the patient as an integrated organism.

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Shear bond strength of composites using an adhesion booster

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Abstract

Objective: To evaluate the shear strength of two composites (Transbond XT and Concise) using an adhesion booster (Ortho Primer). **Methods:** The sample consisted of 90 bovine incisors divided into six groups (n=15). All teeth were subjected to prophylaxis with pumice and enamel etching with phosphoric acid. Transbond XT was used conventionally in Group I. Group II was handled similarly to Group I, except that Ortho Primer was applied instead of XT Primer. After etching, the enamel in Group III was contaminated with saliva, Ortho Primer was then applied and bonding performed using Transbond XT. In Group IV, Concise was used conventionally. Group V was handled similarly to Group IV, except that Ortho Primer was applied instead of the fluid resin. After etching, the enamel in Group VI was contaminated with saliva, Ortho Primer was then applied and bonding performed using Concise. The specimens were stored in distilled water at 37 °C for 24 hours and subjected to shear strength testing. Data were analyzed with ANOVA and Tukey's test (5%). **Results:** Bond strength in Group IV was statistically higher than in Groups II, III and VI ($p < 0.05$). No statistically significant differences were found among Groups I, IV and V, and between I, II, III and VI ($p > 0.05$). When used conventionally, both Transbond XT and Concise yielded the highest bond strength values. When applied to dry enamel, Ortho Primer acted effectively as a bonding agent for the composites under evaluation. When applied to contaminated enamel, Concise yielded low bond strength.

Keywords: Orthodontic brackets. Shear strength. Orthodontics.

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INTRODUCTION

For many years orthodontic treatment was performed with the aid of orthodontic bands placed on all teeth. Not only was this procedure rather laborious, it also caused considerable discomfort to patients, compromised oral hygiene, presented unfavorable esthetics and remaining spaces between the teeth after removal of the orthodontic appliance.^{3,30}

Changing from banding teeth to bonding brackets directly to tooth enamel was one of the most significant advances in orthodontic appliance placement procedures of all times. This procedure was only possible thanks to Buonocore⁸ (1955), who introduced the technique for etching dental enamel with phosphoric acid, and to Newman¹⁹ (1965) who spearheaded the bonding of orthodontic attachments.

Currently, a broad range of orthodontic attachments such as brackets, hooks and tubes are available to orthodontists as well as a variety of bonding materials, among which composites are undoubtedly the most widespread. The procedure for bonding brackets to enamel with these materials needs to be conducted in an orderly and cautious manner in order to prevent bond failures when applying orthodontic mechanics, which might undermine treatment effectiveness. This procedure is time consuming and requires a dry surgical field free from any type of contamination.⁴ The bonding of accessories with composites in the presence of contamination or moisture may cause a higher number of bracket bond failures, delaying treatment and increasing costs to orthodontists.^{2,28}

With the purpose of finding a solution to this critical issue in orthodontic bonding, manufacturers have developed materials that can be used in moist or contaminated environments without compromising bond strength.^{11,12,14,18,29} Additionally, these products save consultation time, decreasing the number of bond failures and consequently affording greater ease and effectiveness to orthodontists.^{21,24,25}

A new product was recently introduced in the market known by its commercial name as Ortho Primer (Morelli, Sorocaba, Brazil). According to the manufacturer it is an adhesion booster with hydrophilic properties suitable for bonding brackets in adverse clinical situations, including cases where saliva or moisture contamination occurs after enamel etching. This material acts as a bonding agent with the function of chemically activating orthodontic composite adhesion and is suitable for all types of brackets.

The mere introduction of a new product in the market, however, is not enough to ensure that such material is suitable for clinical use. Product effectiveness and suitability must be verified in laboratory experiments and clinical trials. The aim of this study was to examine the shear strength of metal brackets bonded with different composites onto dry surfaces contaminated with saliva using Ortho Primer as an adhesion enhancing agent.

MATERIAL AND METHODS

The study made use of 90 right and left mandibular permanent bovine²² incisors, freshly extracted, properly cleaned with periodontal currettes (Duflex, Juiz de Fora, Brazil), which were stored for one week in an aqueous solution of 0.1% thymol and subsequently stored in distilled water in the refrigerator at 4 °C. Criteria for tooth selection required intact crowns, no decalcification (softening), cracks or fractures.

After storage, the teeth were dried and handled in the following manner: The crown and part of the tooth root were placed in a wooden box containing plasticized wax until the desired depth was reached. While placing the teeth in the wax, care was taken to position the buccal surface perpendicular to the bottom of the box. In this position, the remaining portion of the root was centered in a PVC tube (Akros, São Paulo, Brazil) with 20 mm internal diameter by 20 mm height. After this procedure, acrylic resin (Dental Vipi, Pirassununga, Brazil) was poured inside the PVC

tube in the sandy phase under vibration (Fig 1), and the excess removed from the bottom of the die with a LeCron spatula (Duflex, Juiz de Fora, Brazil). Then the tooth crowns were removed from the wax and cleaned (Fig 2).

To verify the correct positioning of the crown in the PVC tube a glass square ruler was used with the 90-degree angle resting on the upper portion of the die and on the buccal surface of each tooth (Figs 3A and B). This verification was necessary to ensure proper shear testing. Badly positioned teeth were excluded from the experiment. The entire tooth-PVC tube set was filled with resin, numbered for better identification and stored again in distilled water under refrigeration.

All buccal surfaces were subjected to prophylaxis with rubber cup, non-fluoridated pumice and water for 10 seconds, then washed and dried for the same period of time. After five prophylaxis procedures the rubber cup was replaced to ensure standardization. Subsequently, all teeth had their enamel etched with phosphoric acid gel at 37% for 30 seconds, followed by washing and drying for about 20 seconds.

The specimens were divided into six groups (n=15), as described in Table 1.

In Groups II, III, V and VI, after Ortho Primer bonding agent had been applied, light-curing was performed for 10 seconds.

Ninety maxillary central incisor metal brackets Dyna-lock Standard, with mesh base, no torque or angulation (code 018-501, 3M Unitek, Monrovia, USA) (Fig 4), were positioned on the buccal surface of each tooth with the aid of bracket placing tweezers (Orthoply, Philadelphia, USA). All bonding procedures were performed by the same examiner after properly positioning each attachment and pressing them against the tooth surface in order to reduce composite thickness between bracket and enamel. At this time, all bonding material excess was removed with an explorer probe (Fig 5).

In the groups using Transbond XT, bonding was light cured for 40 seconds, i.e., 10 seconds on



FIGURE 1 - Steps taken to insert bovine teeth in PVC tube.



FIGURE 2 - Bovine tooth inserted in PVC tube.

each surface (mesial, distal, incisal and gingival) as close as possible to the base of the bracket with a halogen light unit XL 2500 (3M/ESPE, St. Paul, USA) with 500 mW/cm² power. This light intensity was verified prior to each light curing session with a radiometer (Demetron, Danbury, USA).

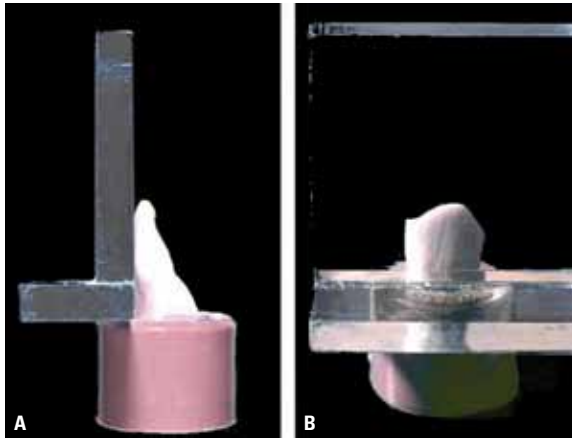


FIGURE 3 - Proper tooth positioning verification. **A)** Lateral view. **B)** Front view.

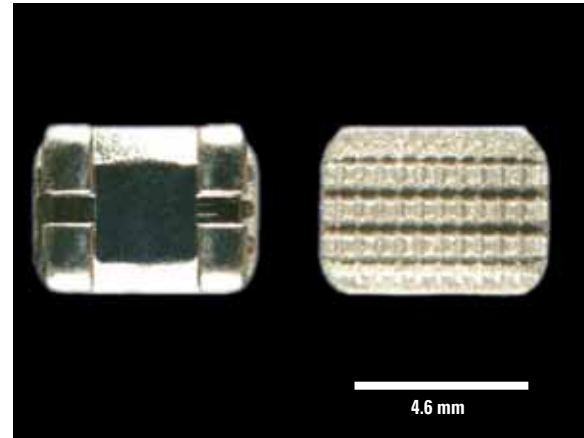


FIGURE 4 - Bracket used in the experiment.



FIGURE 5 - Specimen with bracket bonded to buccal surface.

In the groups using Concise composite no light curing was performed as this is a self-curing material.

After bracket bonding, the specimens were once again stored in distilled water in an oven (Odontobrás, Ribeirão Preto, Brazil) for 24 hours at 37 °C to simulate oral conditions. Thereafter,

TABLE 1 - Groups used in the experiment.

Group	Enamel condition	Bonding agent	Composite
I	Dry	XT Primer	Transbond XT
II	Dry	Ortho Primer	Transbond XT
III	Contaminated with human saliva	Ortho Primer	Transbond XT
IV	Dry	Fluid resin A and B	Concise*
V	Dry	Ortho Primer	Concise*
VI	Contaminated with human saliva	Ortho Primer	Concise*

all samples were subjected to shear bond strength testing on an Instron machine, model 44.11, (Canton, USA) with a speed of 0.5 mm/minute with a chisel-shaped tip resting on the upper enamel/bracket interface.

Shear bond strength values were obtained in Kgf (kilograms-force), transformed into N (Newton) and divided by the area of the bracket base (15.64 mm²), yielding values in MPa.

Statistical treatment

Data on shear strength were analyzed using multifactorial analysis of variance and Tukey's test at 5% level of significance for comparison between groups.

RESULTS

Mean shear strength values obtained for the six groups as well as statistical comparisons between them are shown in Table 2.

Group IV showed a mean shear strength value statistically higher than Groups II, III and VI ($p < 0.05$). Groups I, II and V were statistically higher than Group VI ($p < 0.05$). No statistically significant difference was observed between Groups I, IV and V, between I, II and III, nor between Groups III and VI ($p > 0.05$).

DISCUSSION

In orthodontic bonding, tooth surface conditions and type of bonding material greatly affect bond strength. In some situations, enamel preparation is not adequate to ensure bracket adhesion during orthodontic mechanotherapy, causing treatment delays and damage to tooth structure due to the need for repeated rebonding.^{5,9,10,13,17}

Groups I, II and III were bonded with Transbond XT light-cured composite, a material used as control in several studies available in the lit-

erature.^{1,4,6,7,11,12,15,24,25,26} There were no statistically significant differences between them, regardless of surface treatment. In Group I bracket bonding was performed with Transbond XT in a conventional manner, i.e., according to the manufacturer's directions, yielding a shear strength value of 11.35 MPa. This is close to values found by other authors^{6,7,11,15} and higher than other studies.^{1,25} The differences found between the results of this and other studies are probably due to the different methodologies used during the mechanical tests as well as the different substrates.

Between Groups II (dry enamel, Ortho Primer and bonding with Transbond XT) and III (enamel contaminated with saliva, Ortho Primer and bonding with Transbond XT), the mean shear strength values were very close and therefore not statistically significant. This was not the case with Concise since Group V, where Ortho Primer was used on dry enamel, yielded better adhesion than on saliva-contaminated enamel (Group VI), and was therefore statistically significant.

Self-curing composites – Concise in particular – have been used to bond orthodontic accessories for several decades primarily thanks to their adequate bond strength in a dry environment.^{21,25} Table 2 shows that Group IV, which used Concise as bonding material according to the manufacturer's recommendations, achieved the highest shear strength mean value in this study (16.34 MPa). This is close to values found by other authors^{15,22,27} and higher than other studies cited in the literature.^{1,24}

In situations where maintenance of a dry surgical field becomes challenging, the literature shows inadequate or even absence of bond strength of this type of material (composite) to enamel.¹⁶ Group VI, which was bonded with Concise after application of Ortho Primer to saliva-contaminated enamel, showed the lowest shear strength in this study (5.62 MPa). This result is lower than the value proposed by Reynolds²⁰ for laboratory trials and confirms that saliva contamination after acid etching is a key factor undermining bracket adhesion to

TABLE 2 - Mean shear strength (MPa) and statistical analysis of experimental groups.

Groups	Shear Strength (MPa)
IV	16.34 (4.76) ^a
V	12.43 (3.83) ^{ab}
I	11.35 (3.62) ^{ab}
II	9.85 (3.12) ^b
III	7.68 (4.52) ^{bc}
VI	5.62 (3.33) ^c

Means followed by different letters differ by Tukey's test at 5% level. Standard deviation in parentheses.

enamel using composites.^{10,12} The bond strength of 12.43 MPa found in Group V (dry enamel, Ortho Primer and bonding with Concise) was statistically higher than in Group VI, which reinforces the argument that bonding with composites is significantly enhanced in a dry environment.

Groups V and VI used a light-cured material (Ortho Primer) with a self-curing composite (Concise). Potential lack of compatibility between curing methods²³ was not investigated in this work.

It is worth mentioning the work of Grandhi et al¹⁵ in 2001, who found that the low effectiveness of a self-curing composite (Concise) associated with a hydrophilic primer (Transbond MIP) in a contaminated environment could be related to a failure to activate the hydrophilic primer, since in this experiment the primer was not light-cured prior to bonding. In the present study another hydrophilic bonding agent was utilized (Ortho Primer) which was cured after application. Given these methodological differences one cannot state that light-curing Ortho Primer enhanced bond strength in the infected groups.

In a comparison between bonding materials (Transbond XT and Concise), both showed similar bond strength values in light of a variety of surface treatment approaches and different types of bonding agents (Tables 1 and 2). When the composites were bonded to dry enamel using their respective bonding agents the highest bond strength values were obtained, followed by the condition of dry enamel and saliva-contaminated enamel associated with Ortho Primer, which exhibited lower bond strength values.

CONCLUSIONS

1) Composites Transbond XT and Concise™ Orthodontic Bonding System, when used conventionally, achieved the highest bond strength values.

2) When applied to dry enamel, Ortho Primer acted effectively as a bonding agent for the composites mentioned above.

3) Bonding to surfaces contaminated with saliva using Concise after application of Ortho Primer yielded low bond strength.

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Influence of gingival exposure on the smile esthetics*

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Abstract

Objective: The purpose of this study was to evaluate the influence of gingival exposure on smile esthetics and to compare different opinions among orthodontists, clinicians and laypersons. **Methods:** Photographs of smiling faces of a male and a female subject were manipulated on the computer with different gingival exposure levels, ranging from 4 mm of gingival exposure to 4 mm of upper lip incisor coverage. The photographs were printed in actual size of the face, and randomly analyzed by 30 orthodontists, 30 clinicians and 30 laypersons. The faces were rated as very poor, poor, regular, good and very good according to the smile attractiveness. **Results:** The most attractive female smile, judged by the orthodontists, clinicians and laypersons, was the one where the upper lip rests on the gingival margin of the upper incisor, showing the whole incisor crown ($P \leq 0.05$). For the male subject, the most attractive smile according to laypersons, was the one with the upper lip resting on the gingival margin of the crown of the maxillary incisor; while orthodontists and clinicians considered both the upper lip on the gingival margin of the maxillary incisor's crown and 2 mm upper lip incisor coverage as the most esthetics ($P \leq 0.05$). **Conclusion:** Smile attractiveness is influenced by the gingival exposure, and different opinions are observed among orthodontists, clinicians and laypersons.

Keywords: Esthetics. Smile. Gingival exposure.

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INTRODUCTION

The smile is one of the most important facial expressions and essential for expressing joy, pleasure, mood and gratefulness.¹⁰ The quantity of dental and gingival vertical exposure during smiling is one of the characteristics of interest for smile esthetics.¹³

Gingival smile occurs due to a combination of variables such as: Maxillary vertical excess, high muscular ability to elevate the superior lip when smiling, increased interlabial spacing during resting, and increased overjet and overbite. Variables like upper lip length, clinical crown length, and angles of the mandibular and palatal planes do not seem to influence on the gingival smile.¹⁰ On the other hand, short upper lip and short clinic crown length may contribute for gingival exposure.⁴

Depending on diagnosis, gingival smile treatment may rely on orthodontic, periodontal and surgical therapies.²

Although many orthodontists and clinicians consider gingival smiles as non-desired,^{7,10} this characteristic might not necessarily be unaesthetic to the public eyes.^{2,4} The aim of the present study was to assess which level of gingival exposure is considered more esthetic for males and females, and to compare the differences in opinion among orthodontists, clinicians and laypersons in relation to the gingival exposure for the smile esthetics.

MATERIAL AND METHODS

One female (FS), 21 year-old, and one male (MS), 23 year-old, students of dentistry at the UFSC, presenting aligned teeth and balanced facial proportions were selected for this research. The informed consent was obtained. Color photographs were obtained of full face in frontal view and with spontaneous smile, using a Canon Rebel XT (Japan) camera. The original photographs were manipulated with the software Adobe Photoshop CS 8.0, and the resting

position of the upper lip in relation to the maxillary incisors was modified. These modifications provided 5 levels of gingival exposure, being: 4 mm coverage of the maxillary incisors by the upper lip measured from the gingival margin (-4 mm); 2 mm coverage of the maxillary incisors by the upper lip (-2 mm); upper lip at the level of the maxillary incisors gingival margin (0 mm); 2 mm gingival exposure (+2 mm), and 4 mm gingival exposure (+4 mm) (Figs 1 and 2). The ten photographs, five from each individual, were printed in actual size of the face and were randomly organized and interposed in an album.

Evaluators were composed of 90 people, being 30 orthodontists, 30 clinicians and 30 laypersons. Photographs were evaluated through a questionnaire following 5 esthetics interpretations: Very poor, poor, regular, good and very good (Table 1). The mean age of the orthodontists was 37.6 years (minimum of 23 and maximum of 53 years). The clinicians presented mean age of 29.8 years (minimum of 21 and maximum of 45 years); while the laypersons group (no dental academic education) presented mean age of 33.9 years (minimum of 18 and maximum of 52 years).

STATISTICAL METHODOLOGY

A descriptive analysis of the evaluated photographs was performed and one score was created for each evaluation (Table 1), which was used in the statistical analysis.

Three-way ANOVA for repeated measures assessed possible statistical differences and interactions among the level of gingival exposure (-4 mm, -2 mm, 0 mm, 2 mm, 4 mm), the evaluator category (orthodontist, clinician and layperson) and the gender of the evaluated subject (male or female). The evaluated photographs were paired in relation to the evaluator. T-test was later performed for the variables presenting statistical difference through ANOVA, aiming to perform a more detailed analysis through a two

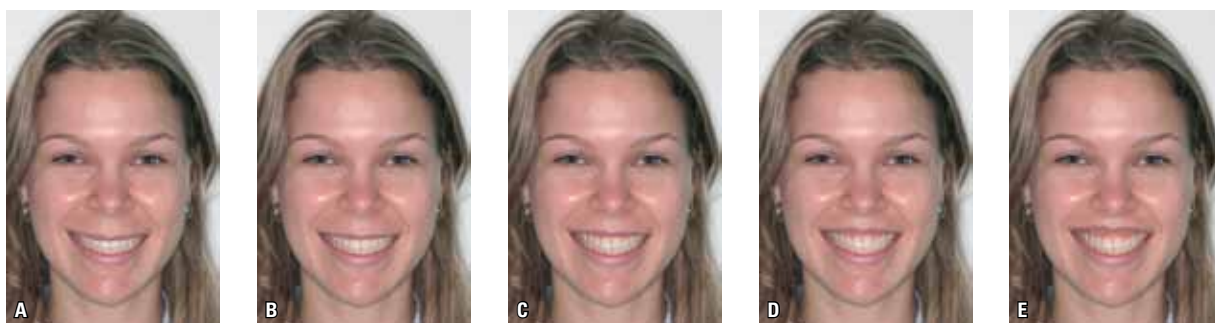


FIGURE 1 - FS photographs. A) -4 mm, B) -2 mm, C) 0 mm, D) +2 mm, E) +4 mm.

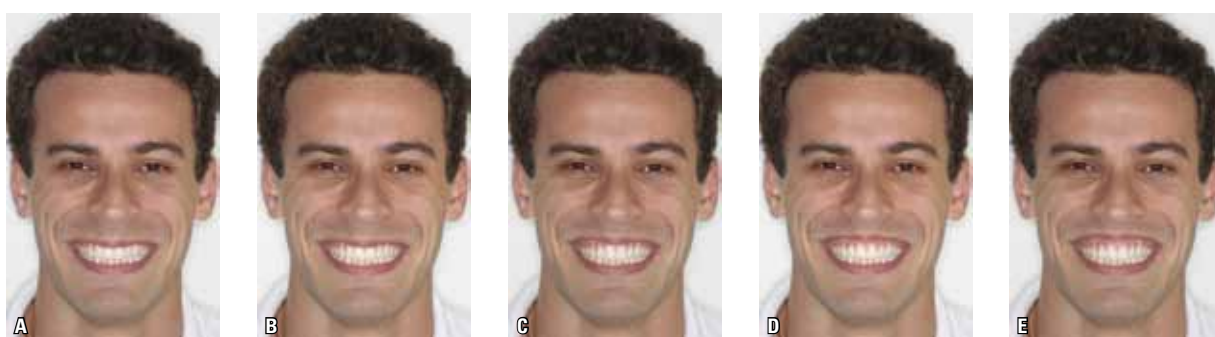


FIGURE 2 - MS photographs. A) -4 mm, B) -2 mm, C) 0 mm, D) +2 mm, E) +4 mm.

Photograph evaluation	Score
Very poor	1
Poor	2
Regular	3
Good	4
Very good	5

TABLE 1 - Scores used by the evaluators for each photograph.

by two comparison of the means. The significance level was set at 5% for both tests ($P \leq 0.05$).

RESULTS

Table 2 shows the frequency of evaluations and mean scores resulting from these frequencies.

Interactions among gender, gingival exposure and evaluator were assessed by means of ANOVA F test at the level of significance of 5% ($P < 0.05$). Multiple comparisons test was employed to assess these interactions (Table 3).

Table 4 presents the comparison among the gingival exposure evaluations for each evaluator category, obtained from the FS and MS photographs. The t test was employed for data analysis.

DISCUSSION

The present results (Tables 3 and 4) showed that orthodontists, clinicians and laypersons considered the smile with the upper lip resting on the gingival margin of the maxillary incisors (0 mm) as being the most esthetic for the female subject (FS) ($P < 0.05$). On the other hand, for the male subject (MS), laypersons considered the most esthetic smile the one with upper lip at the level of gingival margin of the maxillary incisors (0 mm), while orthodontists and clinicians considered more esthetic the smiles with upper lip resting at the gingival margin (0 mm) or covering the maxillary incisors in 2 mm ($P < 0.05$).

TABLE 2 - Descriptive analysis for each gingival exposure and each group of evaluator, for the analysis of the female (FS) and the male subject (MS) photographs.

	Gingival Exposure	Type of Evaluation	Frequency of Evaluations					Scores Mean±SD
			Very poor	Poor	Regular	Good	Very good	
FS	-4 mm	Orthodontist	8	19	3	0	0	1.83±0.59
		Clinician	13	10	2	5	0	1.97±1.10
		Layperson	6	13	8	3	0	2.27±0.91
	-2 mm	Orthodontist	3	11	12	4	0	2.57±0.86
		Clinician	1	11	8	10	0	2.90±0.92
		Layperson	0	7	11	9	3	3.27±0.94
	0 mm	Orthodontist	0	1	2	14	13	4.30±0.75
		Clinician	0	1	4	14	11	4.17±0.79
		Layperson	0	1	1	14	14	4.37±0.72
	+2 mm	Orthodontist	1	4	11	14	0	3.27±0.83
		Clinician	0	2	8	16	4	3.73±0.78
		Layperson	1	1	5	15	8	3.93±0.94
	+4 mm	Orthodontist	12	11	4	2	1	1.97±1.07
		Clinician	12	13	2	3	0	1.87±0.94
		Layperson	6	10	7	7	0	2.50±1.07
MS	-4 mm	Orthodontist	1	7	15	5	2	3.00±0.91
		Clinician	1	9	12	8	0	2.90±0.84
		Layperson	1	5	11	10	3	3.30±0.99
	-2 mm	Orthodontist	0	5	12	11	2	3.33±0.84
		Clinician	0	7	13	6	4	3.23±0.97
		Layperson	0	4	10	12	4	3.53±0.90
	0 mm	Orthodontist	0	1	10	15	4	3.73±0.74
		Clinician	0	2	11	15	2	3.57±0.73
		Layperson	0	2	6	14	8	3.93±0.87
	+2 mm	Orthodontist	2	6	11	7	4	3.17±1.12
		Clinician	3	13	9	4	1	2.57±0.97
		Layperson	2	8	11	8	1	2.93±0.98
	+4 mm	Orthodontist	10	13	5	2	0	1.97±0.89
		Clinician	14	13	1	1	1	1.73±0.94
		Layperson	9	13	6	1	1	2.07±0.98

Another study assessed 454 smiles of 20-30 year-old students.¹⁵ Smiles were divided into three groups: High smile, the one exposing the whole gingivo-incisal length of the incisors crowns and a continuous area of gingiva; mean smile, revealing 75 to 100% of the maxillary incisors crown and the interproximal gingiva;

low smile, revealing less than 75% of the maxillary anterior teeth. The most esthetics results were detected for the mean smile, with total exposure of the incisors' crowns and interproximal gingiva.

Chiche and Pinault¹ reported that exposure of the whole crown of maxillary incisors and

TABLE 3 - Mean scores of the evaluations according to evaluator type, gingival exposure and gender. The statistical significance was determined by the t test.

Gingival exposure	Photographs	Orthodontist	Clinician	Layperson
		Mean±SD	Mean±SD	Mean±SD
-4 mm	FS	1.83±0.59 ^{Aa}	1.97±1.10 ^{Aa}	2.27±0.91 ^{Aa}
	MS	3.00±0.91 ^{Ab}	2.90±0.84 ^{Ab}	3.30±0.99 ^{Ab}
-2 mm	FS	2.57±0.86 ^{Aa}	2.90±0.92 ^{ABa}	3.27±0.94 ^{Ba}
	MS	3.33±0.84 ^{Ab}	3.23±0.97 ^{Aa}	3.53±0.90 ^{Ab}
0 mm	FS	4.30±0.75 ^{Aa}	4.17±0.79 ^{Aa}	4.37±0.72 ^{Aa}
	MS	3.73±0.74 ^{Ab}	3.57±0.73 ^{Ab}	3.93±0.87 ^{Ab}
+2 mm	FS	3.27±0.83 ^{Aa}	3.73±0.78 ^{Ba}	3.93±0.94 ^{Ba}
	MS	3.17±1.12 ^{Aa}	2.57±0.97 ^{Ab}	2.93±0.98 ^{Ab}
+4 mm	FS	1.97±1.07 ^{Aa}	1.87±0.94 ^{Aa}	2.50±1.07 ^{Ba}
	MS	1.97±0.89 ^{Aa}	1.73±0.94 ^{Aa}	2.07±0.98 ^{Ab}

Different UPPERCASE letters indicate statistical difference within the same line, detected by the t test at 5% significance level.

Different LOWERCASE letters indicate statistical difference within the same group of gingival exposure, detected by the t test at 5% significance level. (FS= Female subject. MS= Male subject).

TABLE 4 - Comparison of gingival exposure mean scores according to gender and evaluator category. The statistical significance was determined by the t test.

Evaluator Category	Photographs	-4 mm	-2 mm	0 mm	+2 mm	+4 mm
		Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Orthodontist	FS	1.83±0.59 ^a	2.57±0.86 ^b	4.30±0.75 ^c	3.27±0.83 ^d	1.97±1.07 ^a
	MS	3.00±0.91 ^a	3.33±0.84 ^{ab}	3.73±0.74 ^b	3.17±1.12 ^a	1.97±0.89 ^c
Clinician	FS	1.97±1.10 ^a	2.90±0.92 ^b	4.17±0.79 ^c	3.73±0.78 ^d	1.87±0.94 ^a
	MS	2.90±0.84 ^{ac}	3.23±0.97 ^{ab}	3.57±0.73 ^b	2.57±0.97 ^c	1.73±0.94 ^d
Layperson	FS	2.27±0.91 ^a	3.27±0.94 ^b	4.37±0.72 ^c	3.93±0.94 ^d	2.50±1.07 ^a
	MS	3.30±0.99 ^a	3.53±0.90 ^a	3.93±0.87 ^b	2.93±0.98 ^c	2.07±0.98 ^d

Different LOWERCASE letters indicate statistical difference within the same line, detected by the t test at 5% significance level. (FS= Female subject. MS= Male subject)

1 mm of gingiva is esthetically ideal. However, 2-3 mm of exposure may be esthetically acceptable. Mackley,⁸ studying the evaluation of facial photographs with smiling faces by orthodontists and laypersons, found that more esthetic smiles were those with upper lip at the level of the gingival margin of the maxillary incisors. This fact was also observed by Hulsey³ in photographs evaluated by laypersons. Hunt et al⁴ observed that laypersons determined the most esthetic smile that with no gingival exposure (0 mm); however, the variation between

+2 mm to -2 mm was relatively low. Laypersons according to Geron e Atalia,² considered maxillary incisors covered 0.5 mm by upper lips as the most esthetic smiles. Kokich et al,⁵ found similar results to ours, that laypersons, clinicians and orthodontists found the smile more esthetic when the upper lip rests on the gingival margin (0 mm) or when covering the incisors crown in 2 mm.

For the present study (Tables 3 and 4), smiles with upper lip covering 4 mm of the maxillary incisors' crowns or with 4 mm gingival exposure

were the least esthetic for the female subject according to orthodontists, clinicians and laypersons ($P \leq 0.05$). For the male subject, the least esthetic smile was the one presenting 4 mm gingival exposure, through the evaluation of orthodontists, clinicians and laypersons ($P \leq 0.05$).

Three and four millimeters gingival exposures were progressively related to less attractive smiles in a study by Hunt et al.⁴ Low scores for esthetic smiles were obtained by the study of Hulse³ when 2 mm gingival exposure or incisor coverage by the upper lip greater than 2 mm were observed. However, the study did not assess the influence of gingival exposure greater than 2 mm or incisor coverage lower than 2 mm. The measurements varied from 2 mm incisor coverage by the upper lip to 6 mm gingival exposure in another study by Kokich et al.⁵ The least esthetic smile in this case was the one associated with 6 mm gingival exposure. According to Geron and Atalia,² least attractive smiles presented gingival exposure starting from 1 mm, being 3.3 mm the least esthetic one.

Peck et al.^{10,11,12} found that 1 mm or greater gingival exposure is a characteristic predominantly observed for female subjects, with a frequency rate of two women for each man. They also found that 2 mm or greater incisor coverage by the upper lip is predominantly observed in male subjects, with a frequency of 2.5 men for each woman. Vig and Brundo¹⁶ also detected sexual dimorphism: Gingival smile and maxillary anterior teeth exposure 2.5 times more frequently observed in women, while men presented 2.5 times more frequent exposure of mandibular incisors in comparison to women. Moreover, the upper lip is positioned 1.5 mm more apically in women than in men.¹¹ Vig and Brundo¹⁶ stated the sexual dimorphism is also detected with resting lip, as men tend to expose 1.91 mm of the maxillary incisors, compared to 3.40 mm in the female group.

Although the present study did not aim to

compare different genders in relation to gingival exposure, but to determine the acceptable levels for each one, photographs with smile presenting incisor coverage by the upper lip received higher scores for the male subject in comparison to the female subject ($P \leq 0.05$). The group -2 mm did not differ in relation to gender according to the clinicians. Photographs with gingival exposure and lip resting on the gingival margin (0 mm) received higher scores for the female subject ($P \leq 0.05$). On the other hand, when considering the evaluators groups, there was no statistical difference between genders for the group +4 mm when evaluated by clinicians and for the groups +2 mm and +4 mm when evaluated by orthodontists.

No statistical difference was detected in both genders for the 4 mm incisors coverage (Tables 3 and 4) according to orthodontists, clinicians and laypersons. However, the female subject received lower scores in comparison to the male ($P \leq 0.05$). The scores were considered bad for the female subject and regular for the male.

For the 2 mm incisors crown coverage (Tables 3 and 4), orthodontists scored lower than laypersons for the female subject ($P \leq 0.05$), while no statistical difference was detected for the male subject among orthodontists, clinicians and laypersons. Laypersons and orthodontists scored lower the female subject's photographs in comparison to the male ones ($P \leq 0.05$). The scores were between poor and regular for the female subject in our study, similarly as observed by Hulse³ where 2 mm upper lip coverage was considered unaesthetic. However, the assessment of gingival level in this last study varied only from +2 mm to -2 mm. The same measurements varied from regular to good for the male subject in our study. This was similarly reported by Kokich et al.⁵ when evaluated by orthodontists, clinicians and laypersons, or when evaluated by laypersons according to Geron and Atalia² and Hunt et al.⁴

For the 0 mm group, with the upper lip resting on the gingival margin of the maxillary incisors (Tables 3 and 4), there was no statistical significant difference among orthodontists, clinicians and laypersons; although the female photographs were scored higher in comparison to the male photographs ($P \leq 0.05$). The 0 mm measurement was considered between good and very good for the female subject and between regular and good for the male subject. Smile with lip resting on the gingival margin was considered esthetic by laypersons, clinicians and orthodontists according to Kokich et al,⁵ by laypersons and orthodontists according to Mackley,⁸ and by laypersons in accordance to Geron and Atalia,² Hulse³ and Hunt et al.⁴

Orthodontists scored lower ($P \leq 0.05$) for the female subject comparing to clinicians and laypersons for the 2 mm gingival exposure (Tables 3 and 4). There was no statistical difference among scores from orthodontists, clinicians and laypersons for the male subject ($P \leq 0.05$). The obtained score in the present study was evaluated between regular and good for the female subject, and similarly classified as esthetic by Kokich et al⁶ according to orthodontists, clinicians and laypersons, and also for laypersons according to Hunt et al.⁴ The obtained scores were from poor to regular for the male subject, similarly assessed as unaesthetic by laypersons according to Hulse.³ Geron and Atalia² also reported that laypersons considered unattractive smile when any gingival exposure starting from 1 mm is observed. According to Kokich et al,⁵ although orthodontists considered 2 mm gingival exposure unattractive, clinicians and laypersons considered the smile as being esthetic.

Laypersons rated smiles with 4 mm gingival exposure with higher scores for the female subject (Tables 3 and 4) in comparison to orthodontists and clinicians ($P \leq 0.05$). No statistical difference was detected for the male sub-

ject according to orthodontists, clinicians and laypersons. Laypersons scored higher for the female subject ($P \leq 0.05$). The present score was considered poor for the female subject, and between very poor and poor for the male subject. Similarly to our results, Kokich et al⁵ reported that 4 mm gingival exposure was determined as unattractive by orthodontists, clinicians and laypersons; and also according to laypersons in a study by Hunt et al.⁴ On the other hand, Kokich et al⁶ reported that although orthodontists determined unaesthetic smiles with gingival exposure starting at 3 mm, clinicians and laypersons considered an esthetic smile even with gingival exposure of 4 mm.

Increased maxillary incisors exposure is a youth characteristic, while increased mandibular incisors exposure is an elder characteristic,¹⁷ once gingival exposure of the maxillary incisors tend to decrease with age.^{12,14} Vig and Brundo¹⁶ performed a study with different age groups (29-39, 39-49, 49-59 and over 60 years of age) and detected a decreased maxillary incisors exposure and a gradual increase on exposure of mandibular incisors while in rest. Incisors coverage increases with age, improving esthetics of gingival smiles and worsening esthetics of mean and low smiles, leading to an older appearance.¹²

This change is due to gravity effects on the upper and lower lips. The deepening of perioral tissues is partially due to flattening, stretching and decrease elasticity of skin⁹ and lower facial muscle tone leading to decreased lips movements.^{7,8} Some factors such as sunlight speed up these changes.¹²

For a better understanding of this study one must take into consideration the age group of the studied subjects. Thus, the presented data should be related to youth. Other studies with individuals of different age groups should be conducted in order to provide conclusions for different age groups.

CONCLUSIONS

According to the opinion of orthodontists, clinicians and laypersons, smile attractiveness is influenced by the quantity of gingival exposure. The most attractive smile for the female subject was observed when the upper lip rested on the gingival margin of the maxillary incisors, according to the opinion of the three evaluators

categories. For the male subject, laypersons considered smiles with upper lip resting on the gingival margin of the maxillary incisor as being more esthetic. Orthodontists and clinicians considered esthetic the smiles with the upper lip resting on the gingival margin of the maxillary incisors or when the upper lip covers the gingival area of the maxillary incisors in 2 mm.

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Comparative analysis of rapid maxillary expansion using three brands of fan-type expander screw: Laboratory trial using typodont

Ricardo Damo Meneguzzi*, Luciane Macedo de Menezes**, Susana Maria Deon Rizzato***

Abstract

Introduction: Cleft lip and palate patients usually have severe maxillary deficiencies, particularly in the anterior region of this arch and their treatment should include maxillary expansion. **Objective:** To evaluate the expansion pattern of three brands of fan-type expander screws to correct transverse deficiencies. **Methods:** Eighteen expansions on typodonts were performed with 6 simulations for each group: G1 - Dentaurum® screw; G2 - Leone® screw; and G3 - Morelli® screw. For each trial 13 activations of 2/4 of a turn each were made with a 5.2 mm screw opening. Measurements were made at baseline (T1), after half of the activations (T2) and at the end of the trial (T3). A caliper was used to make the following measurements: Inter-first premolars (IP1), inter-second premolars (IP2) and intermolar (IM) widths and arch length (AL). The Kolmogorov-Smirnov, Tukey, Friedman and ANOVA tests were used to analyze data. **Results:** All groups had a "V" shaped opening pattern and the greater expansion was found in the anterior region of the arch, which was more evident in the G3 (29.58% in IP1 and 9.73% in IM). The increase in AL was similar in G1 and G3 (+12.65% and +12.13%) and the lowest value was found in G2 (+8.23%). **Conclusions:** All the fan-type expander screws used in this study may be used to treat dental arch transverse deficiencies. However, the use of the Morelli screw resulted in a greater opening in the anterior region than in the posterior region, an important characteristic in the treatment of cleft lip and palate patients. Further clinical studies should be conducted to confirm these findings.

Keywords: Cleft lip and palate. Expansion screw. Rapid maxillary expansion.

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INTRODUCTION

The orthodontic condition of cleft lip or cleft lip and palate patients has received special attention in recent years. Although the characteristics of patients with dentofacial anomalies are often similar to those of patients without clefts, the limitations associated with the cleft, as well as those resulting from surgical interventions, should be taken into consideration. The treatment of these patients who have a substantial arch deficiency in the anterior region often requires rapid maxillary expansion (RME) with a greater opening in this region. Cleft patients often have a correct transverse relation in the posterior region of the arch, but a crossbite in the anterior region. Therefore, treatment should rehabilitate the anterior region without negatively affecting the posterior region. The transverse opening rates of conventional expander screws are the same in the anterior and posterior regions, whereas fan-type expander screws provide gradual expansion that is practically zero in the molars region and reaches its maximum value in the canines region. However, it is not clear whether all fan-type expander screws achieve the same results when activated. To find out more about this issue, three commercial brands of fan-type expander screws were compared and their performance in laboratory trials was evaluated.

LITERATURE REVIEW

The dental arch of cleft patients who have not undergone surgery may have transverse deficiencies that are more severe towards the medial and anterior regions because of the mesial displacement of the palatal segments, particularly the smallest segment. In patients who have undergone surgeries, mesial displacements, added to anteroposterior growth limitations, are much greater.^{11,18,24,26,28} Cheiloplasty and palatoplasty can reduce the width and length of the maxillary arch. The muscle belt created by cheiloplasty produces a force strong enough

to explain maxillary sagittal deficiencies, which result in maxillary retrognathism, reducing the height of the middle third of the face and contributing to maxillary transverse deficiencies. Palatoplasty, in turn, is only associated with the reduction of the width of maxillary medial and posterior regions.^{4,11,22,24,26,27,29} Because palatal segments may collapse, bilateral cleft lip and palate patients often need rapid maxillary expansion.^{6,28} At birth, infants with bilateral cleft lip and palate have a greater maxillary arch width in the anterior and posterior regions than infants without clefts. The separation of the palatal processes at this phase leads to an increase in maxillary transverse width, while the lack of lip retention favors the buccal projection of the anterior end of the larger segment, which also results in an increase in the sagittal dimension of the dental arch. After the surgical intervention on lip and palate, there is a decrease in the maxillary arch width.^{18,24,28} The comparison of the shape of the maxillary arches of bilateral cleft lip and palate infants with that of infants without clefts reveals that the first one has a more triangular shape composed of three segments: Anterior, which is the premaxilla and may be centralized or laterally displaced; and two lateral, or palatal, segments.²⁴ Therefore, RME is an option to create additional space in the dental arches. In cleft lip and palate patients, orthodontic treatment is usually restricted to lateral repositioning of palatal segments and alignment of teeth and alveolus.²⁸ Treatment with RME results in the physical separation of the premaxilla and the maxillary palatal segments due to the fact that these are bilateral structures united by the midpalatal suture.^{13,19,20} An factor that must be taken into account in RME is the resistance of the facial bones, assigned to the presence of sutures, such as the midpalatal suture.^{15,19} Expanders produce an orthopedic movement that separates the maxillary bones and, at a lesser degree, buccally moves the teeth. The increase in

maxillary arch width and its orthopedic effect may correct the maxillary transverse relation.^{1,13} As a direct result of expansion, suture opening may move the maxilla forward and downward, which opens the bite and moves point A forward. In several cases, however, these effects are temporary.^{8,14,28}

In the non-cleft patients, the opening of the midpalatal suture results in a diastema between the maxillary central incisors, which is not the case in cleft patients.^{7,8,9,25,28} In patients with clefts, however, the separation occurs in the suture between the maxilla and the premaxilla, and there is no bone gain because the midpalatal suture is not involved.^{5,28} The expansion pattern is also triangular as in non-cleft patients and there is a greater opening in the anterior region.^{6,8} Once the desired expansion is achieved, the screw is fixed in place using acrylic resin. The appliance is kept in the mouth for 3 months for retention and to reduce the chances of relapse.^{9,13,17,20}

Adkins et al¹ found that every millimeter increased in palatal width in the premolars region produces a 0.7 mm increase in the maxillary arch perimeter. RME using expanders promotes molars buccal tipping due to the lateral rotation of the alveolar processes and tooth tipping in the alveolar bone, which is followed by some extrusion.^{3,19} Therefore, the maxilla of cleft patients may be seen as segments that RME may spatially reposition.²⁸ In these patients, the narrowing of the maxillary arch is found at a more anterior position and the transverse relation is usually adequate in the posterior region.⁴ Therefore, an expansion screw should provide greater expansion in the anterior region of the arch. In the study conducted by Doruk et al,¹² the group treated using an appliance with a fan-type expansion screw had less posterior teeth tipping and extrusion, which produced an increase in facial height, than the group treated with a conventional expansion appliance. The activation of the fan-type appliance produces gradual expansion that is practi-

cally zero in the posterior region and reaches the greatest value in the anterior region.^{5,12} The results of RME using conventional screws are well documented in the literature. However, studies using fan-type expansion screws should be conducted to evaluate their clinical response, particularly in cleft lip and palate patients. This study evaluated the opening pattern produced by three brands of fan-type expansion screws in laboratory trials using typodont models.

MATERIAL AND METHODS

The sample comprised three types of fan-type expansion screws for maxillary expansion: A Leone[®] one-piece fan-type expansion screw, a Dentaurum[®] two-piece fan-type expansion screw and a Morelli[®] two-piece fan-type expansion screw. To evaluate the opening pattern of each screw, the characteristics of malocclusion usually found in cleft lip or cleft lip and palate patients were reproduced in a typodont. Maxillary deficiency was replicated in typodonts 6 times for each expansion screw, at a total of 18 simulations. To ensure that malocclusion characteristics were reproduced in all trials, a silicone impression was taken for each typodont and an acrylic resin model was fabricated to be used as a reference in the reproduction of malocclusion characteristics. The expansion appliance was manufactured according to the characteristics designed by Haas¹³ and fixed with glass ionomer cement. In a bath with water at a constant temperature of 50 °C, each typodont and its expander was immersed for about 3 minutes. After that, the screw was activated 2/4 of a turn and the typodont was immersed for 2 more minutes for the wax to dissipate the pressure generated by the activation. After that, the typodont was kept under running water for 2 minutes to reach room temperature and to stabilize the activation. Activations were repeated 13 times for each appliance, at a total of 5.2 mm for each screw. At the time of each activation, the following measurements were made: Inter-first premolars (IP1), inter-second

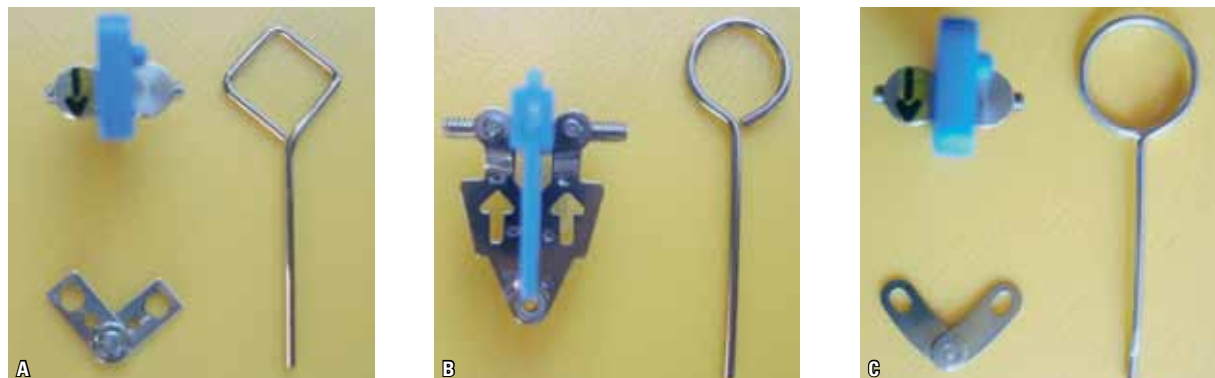


FIGURE 1 - Fan-type expansion screws used in this study. **A)** Morelli®. **B)** Dentaureum®. **C)** Leone®.

premolars (IP2) and intermolar (IM) widths. In addition, the maxillary arch length (AL) was measured before and after activations, as well as the height between the tip of the cusp (buccal) of the maxillary first premolars (BD1) and first molars (BD2) and the typodont base to check possible changes in the vertical dimension of these teeth. A Dentaureum® caliper with precision of 0.01 mm was used for the measurements. The complete activation sequence (13 activations) was repeated for each expansion screw (3 types) and their corresponding expansion appliances for 6 times, at a total of 18 immersions and 13 activations for each one. Data were recorded in spreadsheets for later analysis. Measurements were made at three time points: Before activations (T1), after half of the activations had been done (T2) and after activations (T3). Data were analyzed statistically. To check whether data were normally distributed, the nonparametric Kolmogorov-Smirnov test was used. Analysis of variance (ANOVA) and the Tukey test for multiple comparisons were used to compare groups to each other. The nonparametric Friedman test was used for the comparisons between activations because data were paired.

RESULTS

The analysis of the transverse width of the arch at IP1 revealed that all screws had similar performances in amount of expansion. However, the Leone group, particularly halfway through and after activations, had the greatest IP2 and IM values resulting from expansion. When comparing the increase obtained after activations with baseline (T1) values, results revealed again that the Leone screw had the greatest expansion values, particularly in IP2 and IM widths (Tables 1, 2 and 3).

DISCUSSION

This study is a laboratory trial and results must be interpreted cautiously. Conventional expansion screws have a characteristic pattern of midpalatal suture opening. They produce a considerable increase in intermolar and interfirst premolar widths. This clinical response may be useful when maxillary deficiency is not severe because anterior and posterior crossbites are usually associated in these cases. Adkins et al¹ studied 21 teenagers, nine of them with cleft lip or cleft lip and palate. They used Hyrax

TABLE 1 - IP1, IP2 and IM width increases (percentage) after activations compared with values before activation between groups.

Comparison	n	Mean increase (%)	Standard deviation	p
IP1				
Dentaurum group	6	30.60 ^A	2.84	0.07
Leone group	6	27.29 ^A	1.87	
Morelli group	6	29.58 ^A	2.10	
IP2				
Dentaurum group	6	20.95 ^A	2.70	0.01*
Leone group	6	27.10 ^B	1.63	
Morelli group	6	18.83 ^A	2.09	
IM				
Dentaurum group	6	12.33 ^A	0.17	0.01*
Leone group	6	19.18 ^B	1.08	
Morelli group	6	9.73 ^C	2.17	

* mean values followed by the same letter do not differ from each other.

TABLE 2 - Comparison between groups of IP1 width increase (percentage) in relation to IM after activations.

Comparison	n	Mean increase (%)	Standard deviation	p
Dentaurum group	6	148.37 ^A	24.79	0.01*
Leone group	6	43.00 ^B	16.21	0.01*
Morelli group	6	213.14 ^C	51.37	0.01*

* mean values followed by the same letter do not differ from each other.

TABLE 3 - Comparison between groups of maxillary arch increase (percentage) after activations in relation to AL before activations.

Increase % comparison	n	mean	Standard deviation	p
Dentaurum group	6	12.65 ^A	0.70	0.01*
Leone group	6	8.23 ^B	0.68	0.01*
Morelli group	6	12.13 ^A	1.28	0.01*

* mean values followed by the same letter do not differ from each other.

screws fixed to the bands around the maxillary first premolars and first molars and found similar values of intermolar and inter-premolar widths (about 6.5 mm), whereas the intercanine width had a 50% lower expansion than

the other regions. Capelozza Filho et al⁷ conducted a study on non-surgically assisted RME in adult patients and found that the increase of intermolar and inter-premolar widths was similar (about 3.5 mm), whereas the increase of intercanine width was negligible. Handelman¹⁶ also evaluated non-surgically assisted RME in adults and found increases of 3.9 to 7.5 mm in intermolar width, whereas inter-premolar width increased 1.7 to 9.1 mm. In another study using a group of children whose mean age was 9.5 years and a group of adults with a mean age of 30 years, all without cleft lip or palate, Handelman et al¹⁷ reported the following expansion results: Intermolar width – 5.7 mm (children) and 4.6 mm (adults); inter-premolar width – 4.9 to 5.7 mm (children) and 4.7 to 5.5 mm (adults); and intercanine width – 4.2 mm (children) and 2.8 mm (adults). However, Lamparski et al²⁰ found that appliances using conventional screws and anchored to 2 or 4 teeth had an equivalent mean width (about 5 mm) in the intercanine and intermolar regions. McNamara et al²³ found that the intermolar, inter-premolar and intercanine widths did not differ statistically from each other after expansion with a conventional screw. Cavassan et al⁹ measured the expansion in a cleft lip and palate patient treated with a conventional expansion screw. Intermolar and inter-premolar widths were similar, but the intercanine width was smaller. Therefore, maxillary expansion with a conventional screw corrects deficiencies in anterior region as well as in the posterior region. Table 4 summarizes some of the studies about RME. Cleft lip and palate patients, however, usually have a good transverse relation in the intermolar region, but a deficiency in the anterior region of the arch. Therefore, fan-type expansion screws seem to be appropriate to correct this type of maxillary deficiency. However, few studies have used this type of expansion screw, although they have been available in the market for several years,

Author	n	Age	IC	IP1	IP2	IM
Adkins et al ¹	21	11-17 yr	2.9	6.1		6.5
Capellozza et al ⁷	38	20 yr 8 mo	1.4	3.6		3.2
Handelman et al ¹⁷	47	9 yr 5 mo	2.8	4.7	5.5	4.6
	47	29 yr 9 mo	4.2	4.9	5.7	5.7
Baccetti et al ²	29	11 yr				9.3
	13	13 yr				8.9
McNamara et al ²³	112	12 yr 2 mo	3.9	4.9	4.9	4.4
Doruk et al ¹²	17	12 yr 5 mo	8.1			2.6
Lagravère et al ²¹			4.5 – 8.8			4.3 – 6.3

TABLE 4 - Comparison of measurements obtained in some studies about RME.

and it is complicated to compare the results of the present study with findings in the literature. Moreover, this study is a laboratory trial and typodont models have not been used for the evaluation of even conventional screws.

The analysis of the mean increase percentage between IP1 and IM widths revealed that the Leone screw had an IP1 expansion about 43% greater than the IM width. The Dentaurem screw, in turn, produced an IP1 increase about 143% greater than the IM width. However, the best response was obtained with the Morelli screw, in which the mean increase of the IP1 width was 213% over IM width. The ratio of increase of the transverse width of the anterior region in comparison with the posterior region was 2:1 for the Dentaurem screw, 3:2 for the Leone screw and 3:1 for the Morelli screw. The comparison of the three brands revealed that the Morelli screw had the best expansion pattern for cases in which a greater opening in the anterior region is required. The anterior region had a much more intense response than the posterior region, which had a much smaller expansion. Such results are in agreement with those reported by Capellozza Filho et al⁵, who

found 7 mm of expansion in the intercanine region and only 3 mm in the intermolar region using a Dentaurem fan-type expansion screw. Doruk et al¹² also found an expansion ratio of 3:1 between the intercanine and intermolar regions when using a Leone fan-type expansion screw. These findings define the opening pattern for this type of screw, which has the shape of a triangle with its base turned to the anterior region of the arch. In this study, however, the Leone screw produced the greatest opening in the IM region, similar to that found in IP1, which was similar to the behavior of conventional screws. Moreover, it is an imported screw in Brazil and its prices are high compared to others. The Dentaurem screw had a satisfactory performance in terms of pattern and amount of expansion obtained. However, its performance is not comparable to the results obtained when the Morelli screw was used. The Dentaurem and the Leone screws are imported and have a high cost in Brazil. The Morelli screw was the one that corresponded most to the expectations in this study. It had the best expansion pattern, being manufactured in Brazil and its cost is much lower than that of the other two brands.

The analysis of AL revealed that the increase of this measure was similar for the Dentaurem and the Morelli screws (about 12%). The Leone screw, in turn, had the lowest AL increase. Adkins et al¹ found an arch length decrease of about 0.4 mm after expansion with Hyrax screws, probably due to the palatal tipping of maxillary central incisors. In contrast, McNamara et al²³ found a mean increase of 0.2 mm in this measure after RME using a conventional expander.

The evaluation of the vertical dimension of the teeth that served as anchorage for the appliance revealed that both BD1 and BD2 in all test groups increased after activations, and this difference was greater in the Dentaurem group (mean 6%). Handelman et al¹⁷ compared RME characteristics in a study of conventional Haas appliances used to treat children whose mean

age was 9.5 years and adults about 30 years old. They found that only in the group of children there was some molar extrusion (1.5 mm).

The analysis of our results may provide an estimation of the clinical performance of these screws. As mentioned above, in patients with cleft lip and palate RME does not separate the palatal maxillary processes, but spatially repositions them. Our study may serve as subsidy for further investigations about this issue but, most of all, should motivate other authors to clinically test these screw brands to determine whether they are a treatment option to correct transverse maxillary deficiencies, particularly in the anterior region of the dental arch.

CONCLUSIONS

The results of this study suggest that:

- » Both the Morelli and the Dentaurem screws have a “V” shape opening pattern and greater expansion in the anterior region of the arch, whereas the Leone screw had a more parallel expansion pattern in the anterior and posterior regions of the arch.
- » The increase in arch length (AL) was similar for the Dentaurem and Morelli screws and lower for the Leone screw.
- » There was some increase in the vertical dimension of the teeth that anchored the appliance in all trials, regardless of the brand of the fan-type expansion screw.

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Profile evaluation of orthodontic professionals as for their legal actions

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Abstract

Objective: Evaluate the legal actions and behavior in the doctor/patient relationship, used by dental surgeons practicing orthodontics. **Methods:** The population sample of the present study consisted of dental surgeons, active in the field of orthodontics, and registered with Dental Press Publishing Company — Maringá/PR, Brazil, with a total sample size of 525 professionals. The research was conducted using a 17-question survey forwarded to these professionals. **Results and Conclusions:** The majority of participants in our study are specialized in orthodontics; 75% of professionals use some sort of contract at the office/clinic; 73.7% of professionals periodically request maintenance X-rays; a large percentage of professionals (58.9%) keep patient records on file for life. The interviewed professionals demonstrate good knowledge of the Brazilian Code of Ethics in Dentistry, especially of Chapter XIV — on Communication.

Keywords: Professional practice. Legal liability. Orthodontics. Enacted statutes.

INTRODUCTION

Following the enactment of Brazilian Law 8078/90¹ (Consumer Defense Code), patients began claiming their legal rights, making dental surgeon become ever more careful regarding possible lawsuits. In order to minimize this type of legal problem, it is necessary to compile and maintain full dental records, containing all patient documents and information.

These documents are a set of declarations signed by the professional over the course of treatment, which serve as proof and can be used for legal, forensic^{2,3} and administrative purposes. They consist of the anamnesis, dental services contract, informed consent, clinical evolution of treatment, as well as copies of prescriptions, certificates and referral letters.⁴

The dental services contract should contain all necessary information on orthodontics, its

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risks and benefits, services, diagnosis, prognosis and treatment plan, as well as the estimated cost and duration of treatment, in addition to pertinent information on appliances and the post-treatment period.⁴

Thus, this contract expresses the conditions and limitations of the orthodontist as a rehabilitator, along with patient consent and comprehension. It is an agreement between two or more persons, on account of a licit and possible object, with the intent of acquiring, preserving, modifying or extinguishing rights.^{5,6}

The rise in lawsuits is due to the general lack of information given to patients, turning them into litigants. Therefore, it becomes necessary to clarify the objectives aimed at the conclusion of treatment, what functional benefits there are, and what type of improvement the treatment will provide in terms of dental and facial esthetics.

Thus, the present work had as objective to evaluate the profile of orthodontic professionals with regard to legal actions.

LITERATURE REVIEW

Analyzing the professional/patient relationship with regard to possible legal problems originating from orthodontic treatment, Koubik et al.⁷, in 1995, concluded that dental surgeons should act honestly with their patients, obtaining full and detailed clinical documentation, establishing a legal relationship based on common agreement. This will consequently lead to a stable relationship between the two parties, avoiding future problems with regard to jurisdiction.

In 2006, Melani and Silva⁶ applied surveys to orthodontists and their respective patients, with the objective of investigating this professional/patient relationship, analyzing the legal aspects that guide orthodontic treatment. It was concluded that dental surgeons do not give importance to a well-devised record sheet, containing clear and written data on their patients, which could discharge them in ethics and civil liability lawsuits,

as these records would serve as the orthodontist's main defense tool. Professionals have worried only about contracts that express compensations and periodical maintenance, due to concern with the financial aspect of treatment.

Rodrigues et al.⁸ reviewed the literature on civil liability of orthodontists, clarifying the rights and obligations in professional/patient relationships. They concluded that dentists should adopt conducts based on ethical-legal precepts, avoiding an undesired involvement in legal suits. Therefore, professionals should act according to their abilities and the knowledge expected from a prudent doctor. With regard to the patients, they should be compensated by the professional in case of any injury caused to their health, as described in Art. 949 of the Brazilian Civil Code, which states: "The offender shall compensate the aggrieved party for expenses of the treatment and loss of profits until the end of the convalescence, in addition to any other damages the aggrieved party can prove".

Garbin et al.⁹ in 2006, applied surveys directed at dentists, with questions that assessed their conduct regarding patient records. After analyzing the results, it was observed that, even with the possibility of facing lawsuits, many professionals are negligent towards patient documentation. As such, there is a need to make dentists aware of these aspects.

A statistical census was carried out by Soares et al.³ in 2007, using a survey aimed at Brazilian orthodontists enrolled in the Federal Dentistry Council (CFO), with the objective of analyzing patient/professional relationships in light of the Consumer Defense Code (CDC), the obligatory nature of orthodontic services, and patient awareness of the risks they may face during orthodontic treatment. They concluded that orthodontists are aware of the need to put in practice the rules of the CDC as service providers to their customers — in their case, their patients. Nonetheless, only a minority regarded orthodontics as a duty of due

activity and make patients aware of the risks they face, verbally and in writing.

Kliemann and Calvielli¹⁰ analyzed the legal understanding on obligations resulting from contract relationships and the correlations between these obligations and the activity of dentistry. They acknowledged the real importance of dental surgeons knowing these pre-established conditions with their patients — after all, it is not enough to have knowledge and technique to execute a procedure; one must have professional conduct and well-defined record procedures, with the objective of preventing legal implications resulting from non-observance of these contractual obligations.

MATERIAL AND METHODS

Criterion for choosing the professionals in the study

Questionnaires were distributed to dental surgeons active in the field of orthodontics, from different regions in Brazil, registered with Dental Press Publishing Company — Maringá/PR, Brazil.

Data collection

A total of 525 questionnaires were sent out, containing 17 structured and open questions directed at dental surgeons. Participants received the questionnaire and a letter requesting their participation in the survey via e-mail. The confidentiality of the information provided was assured, as well as their use exclusively for research purposes. Questionnaires were not identified.

Return for data collection was previously arranged with the professionals, with a maximum period of one month after delivery. After the questionnaires were returned, the data were compiled and distributed in percentages, using graphs to demonstrate the result.

The questionnaires

The survey took into consideration the characteristics of training within orthodontics and

knowledge of legal dentistry. Next, the following questions were presented: Whether dental surgeons use any type of contract in the office and/or clinic, and for how long; whether they inform the treatment plan and mode of payment to patients; whether they usually offer more than one treatment option and time estimate; what conduct is adopted if the patient is absent more than three times; whether they use patient images in folders, printouts, newspapers, TV ads or in classes; whether they advertise treatment photographs in printouts, showing the start and end of treatment, and whether they have legal authorization from patients or guardians; whether they advertise costs or modes of payment; whether they have had legal problems, and how they were solved; which items they request for initial orthodontic documentation and how often they request control X-rays; and whether they keep patient records on file, and for how long.

RESULTS AND DISCUSSION

The sample consisted of 525 dental surgeons active in orthodontics. When questioned on their training, most were specialists in orthodontics, as shown in Figure 1.

Dental services contract

All dental surgeons should include the dental services contract in their practices, explaining the main obligations involved in rendering dental services, establishing a legal relationship¹¹ and secondary obligations, in order to prepare or assure the perfect accomplishment of the main obligation.

This contract should be drafted in simple language, containing only the necessary scientific terms, clarifying what will be done within the specialty, informing the risks and benefits of treatment, all possible treatment options within technical-biological limits, how the service will be performed, as well as informing post-treatment precautions, which are usually neglected items.¹²

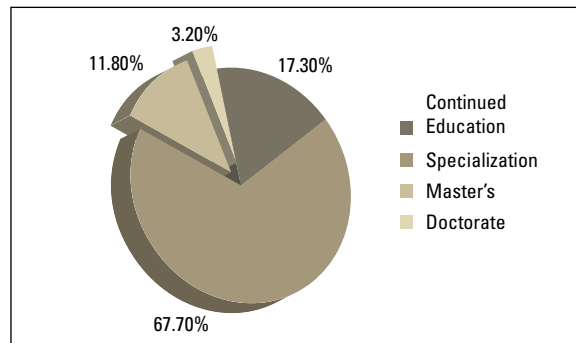


FIGURE 1 - Professional training of the population sampled in this work.

Also part of the obligations concerning dental contracts are biosafety, continuity of treatment, payment of fees, professional secrecy, protection and care, and the place where the dental surgeon monitors the patient, with the intent of highlighting the importance of fulfilling their obligations.¹⁰

It is important that the patient be given proper instructions on hygiene when this guideline is not expressed in the contract, thereby preventing the onset of periodontal disease that could put the treatment in jeopardy. Clarifications should also be made on which type of toothbrush to use, type of dental floss, use of threaders and mouthwash, in order to eliminate and prevent the formation of dental biofilm.

The best way for dental surgeons to legally protect themselves is through documentation.^{4,6,7,10,12} Garbin et al⁹ observed that most dentists (66%) do not have a formal term of service agreement. Melani et al⁶ reported that 53% of patients affirmed having signed some sort of document prior to starting treatment. In the present study, most specialists in orthodontics (61%) use a written and signed dental contract, as shown in Figure 2.

This study showed that 75% of professionals use some sort of contract in their practice and/or clinic. Most professionals in the sample are more careful with this procedure, and 55% have

already used this type of procedure for 1 to 5 years, 37% for 6 to 10 years, and 10.30% have used it for over 10 years, as shown in Figure 3.

Melani et al⁶ observed that few orthodontists (28%) inform their patients in writing about the length of treatment. In our work, 78.9% of dental surgeons define the duration of treatment for their patients, and 21.1% do not.

With regard to the risks of orthodontic treatment, Soares et al,³ in 2007, observed that 1.23% of orthodontists do not report this factor to patients, 2.52% did not answer the question, 4.29% report the risks in writing, 28.66% report them orally, and 63.31% do so both orally and in writing. Furthermore, 19% of dental surgeons pass on information to their patients orally, 17% in writing, 61% in writing and signed, and 3% use other methods. Rodrigues et al⁸ agree with reporting treatment risks to patients, among other issues.

Thus, it is recommended that after diagnosis, treatment options be described with their respective prognoses, letting the patient choose the most adequate treatment option. It is necessary to explain well to the patient the limits, restrictions and contraindications of each option, informing everything that could interfere directly or indirectly on the result the professional can offer and the patient expectations.^{11,12,13}

Therefore, it is important to offer more than one form of treatment to patients.^{7,11,13} This is in accordance with our results, in which most dental surgeons (83.4%) present more than one treatment option to patients.

According to the Code of Ethics in Dentistry¹⁴ — chapter V, section I, Art. 7, clause IV — it is an ethical infraction to “not clearly express the purposes, risks, costs and alternatives of treatment”. In the Consumer Defense Code,¹ Art. 31, “The offer and presentation of products or services shall ensure a correct, clear, accurate and noticeable information on their characteristics, quality, quantity, components, price, warranty,

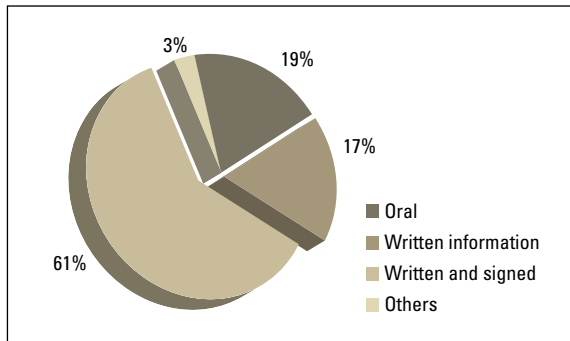


FIGURE 2 - Percentage distribution of the manner in which most specialists in orthodontics use the free and informed consent form.

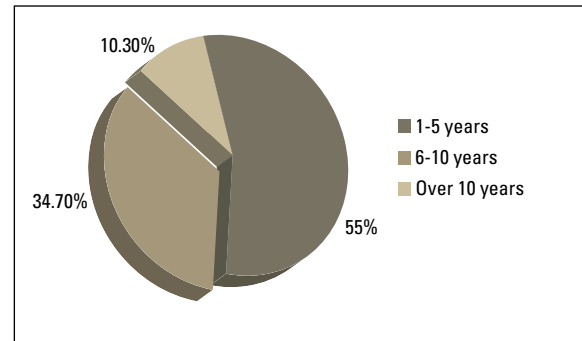


FIGURE 3 - Usage time of the contract in dental clinics of the evaluated sample.

duration and origin, among other data, as well as about the risks they might involve to consumers' health and safety".

In the present study it was observed that 92.2% of consulted sample had not had legal problems with their patients, while 7.8% had legal involvements. A good relationship between professional and patient avoids litigious involvement, preventing civil liability suits against the orthodontist^{4,6,7,9,10,15}. It was further observed that 41.5% of dental surgeons who were involved in suits solved the issue in small claims court, 29.3% in regular courts, 24.4% in the Regional Dentistry Council, 2.4% in the consumer advocate agency, and 2.4% did not answer the question.

The Consumer Defense Code¹, Law 8078/90, in articles 2 and 3, transforms dental surgeons into providers, patients in consumers, and dentistry in a rendered service. Therefore, in any dentist/patient relationship, everything must be made clear, in order to avoid legal troubles in the future. Article 14 states, "The personal responsibility of independent professionals shall be determined upon verification of fault".

The Brazilian Civil Code,¹⁶ in its article 186, states that "incurs in an illegal act one that violates or causes harm to third parties' rights, by means of action or voluntary omission, neglect or imprudence, even if exclusively a moral harm",

and should repair the damage done to the other party (Art. 927). The code also expresses, in Art. 951, that damages should be paid by whomever, in the practice of their professional activity, by negligence, malpractice or incompetence, causes the patient's death, worsens their condition, causes lesions or lead to work disability.

At the end of the dental services contract, the patient's authorization should be requested to execute treatment, for publication in scientific articles or even commercial advertisements, always respecting the patient's anonymity.⁴ The present study showed that 26.1% of dental surgeons used images of their patients in folders, newspapers, TV ads or in classes.

Patient or guardian signature on the record documents confirm the consent and approval for the procedure or fact in question, as determined by the Brazilian Civil Procedure Code¹⁷ — Section V — On Documentary Evidence — Art. 368. "The declarations contained in a private document, written and signed, or only signed, are presumed to be true with regard to the signatory".

The Code of Ethics in Dentistry¹⁴ states it is an ethical infraction within Chapter XIV — On Communication (sections I and III) to publish, without written consent, any element that identifies the patient, exposing their privacy. Our study showed that 43.2% of professionals

have authorization from the patient or guardian for these publications, 41.7% do not, and 15.1% did not answer. To publicize advertising gimmicks to attract clientele, particularly if using the terms “before” and “after” is illicit as well. A total of 12.8% of treatment photographs in printouts show the beginning and end of treatment, while 87.2% do not.

The Code of Ethics in Dentistry¹⁴ states it is an ethics infraction to advertise prices, free services and modes of payment that represent unfair competition. The present study showed that 0.4% advertise pricing and mode of payment, whereas 99% do not, and 0.6% did not answer.

Legal guidance for orthodontists

What to do with dental records at the end of treatment? This is a very common question among orthodontists. To answer that question, Garbin et al¹³ conducted a study with 56 dental surgeons. Most of them (98%) keep records on file, while 2% give them to patients without keeping a copy for their records. Most keep these records, but for how long? This study showed that 1.5% of professionals keep patient dental records for 1 year; 2.3% for 2 years; 20.6% for 5 years; 15.8% for 10 years; 58.9% for life (Fig 4). It should be highlighted that all records belong to the patient, and the best conduct would be to keep them on file for five years, and then return them with an itemized receipt signed by the patient or guardian.

Complete orthodontic records should consist of intra- and extraoral photographs, panoramic X-ray and lateral cephalometric and periapical radiographs of all teeth, and cast models. A total of 0.6% of den-

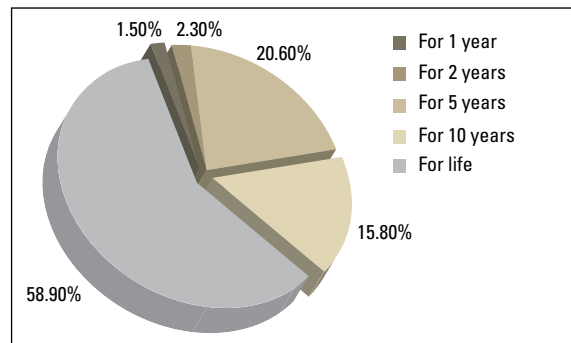


FIGURE 4 - Percentage distribution of the length of dental record storage.

tists affirmed they request only panoramic radiographs; 0.9% request panoramic and lateral cephalometric radiographs and cast models; 64% request panoramic and lateral cephalometric radiographs with cephalometric tracing, intra- and extraoral photographs, periapical radiographs of the incisors and cast models; 25% request panoramic and lateral cephalometric radiograph with cephalometric tracing, intra- and extraoral photographs and cast models; and only 9.5% request all of these exams as well as periapical radiographs of the entire mouth.

Requesting control X-rays (every six months) is essential to detect possible resorption during orthodontic treatment, as is updating patient records, in accordance with the Code of Ethics in Dentistry.¹⁴ In our work, 33.5% of professionals requested control X-rays every six months, 40.2% once a year, 19.0% at the start and end of treatment, 6.1% request them only at the start of treatment, and 1.2% did not answer (Fig 5).

When patients are absent, Garbin et al⁹ affirmed that 73% of dental surgeons only call them to schedule a new appointment, awaiting their return. With regard to the prevalence of professionals who send registered correspondence or telegram by phone, the prevalence was 16.41%. In our study, 60.6% of orthodontists make phone contact with their patients; 2.7% contact by letter; 28.7% by registered letter; 8% await patient contact. In case of patient absence for more than 30 days, it is suggested the patient be contacted by phone; if even then the patient does not come to the appointment, a registered letter should be sent, keeping a copy in the patient's records. The letter should make it clear that not attending will result in risks and non-return will characterize abandonment of treatment.

This survey inquired how professionals obtained their ethics and legal training; 36.3% answered it was during undergraduate studies, 45.9% in graduate school, 15.5% in conferences, CRO (Regional Council of Dentistry) and literature, and 2.3% did not answer. It is noteworthy that, according to the Consolidated Rules for Proceedings in Dentistry Councils,¹⁸ specialization courses are required to offer 30 hours of Ethics and Legislation and 15 hours of Bioethics courses. This suggests that many programs are not giving proper emphasis on these disciplines, being subject to penalties by disobeying Resolution CFO-63/2005.¹⁸ A good relationship with patients, technical-scientific training and legal background assure an excellent level of service and treatment by dentists, as well as protection against lawsuits.^{4,15,19,20}

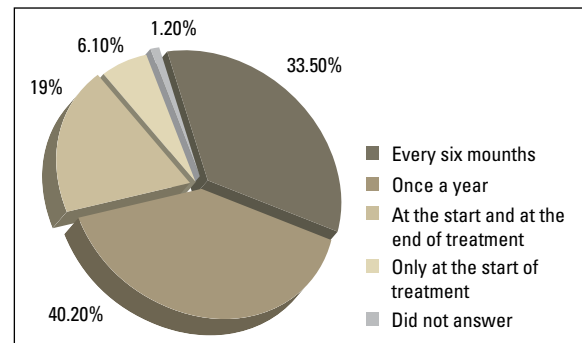


FIGURE 5 - Percentage distribution of the frequency in which control X-rays are taken during orthodontic treatment.

CONCLUSION

Based on the obtained results, it can be concluded that:

- 1) Most participants in the sample are specialists in orthodontics, and 75% use some sort of contract in their practice and/or clinic.
- 2) 92.2% of the sampled professionals have not had legal problems with their patients.
- 3) 73.7% of professionals periodically request maintenance X-rays.
- 4) A large part of professionals (58.9%) keep patient records for life.
- 5) The consulted professionals showed good knowledge of the Code of Ethics in Dentistry, particularly Chapter XIV — On communication.

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Serial extraction: Variables associated to the extraction of premolars

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Abstract

Objective: To determine the frequency of patients who require extraction of permanent premolars among those treated with extraction of deciduous teeth for the correction of incisor crowding in the mixed dentition and analyze possible associated variables. **Methods:** The sample was composed of orthodontic records of 70 patients with permanent dentition whose treatment had begun in the mixed dentition phase and involved serial extraction. All records were analyzed by a single examiner to determine whether serial extraction had been performed with extraction of permanent teeth or only deciduous teeth. Associations were investigated between extraction of permanent teeth and lateral facial pattern, sagittal relationship of the dental arches, incisor-mandibular plane angle, size proportion of mandibular second molar/retromolar space, mechanics for space control and tooth-arch size discrepancy (Fisher's exact test for categorical variables and logistic regression for numeric variables, $p < 0.05$). **Results:** Among the patients who had been treated with extraction of deciduous teeth, 70% required the extraction of permanent teeth. The statistical analysis revealed no significant associations between the analyzed variables and the need for permanent tooth extraction, with the exception of tooth-arch size discrepancy. **Conclusion:** Tooth-arch size discrepancy was the main factor determining premolar extraction in a serial extraction program.

Keywords: Malocclusion. Mixed dentition. Serial extraction.

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INTRODUCTION

From the orthodontic point of view, crowding of deciduous teeth requires solid, coherent treatment, as it affects approximately 50% of children in the mixed dentition phase.¹⁴ Crowding is a dental irregularity caused by a negative tooth-bone discrepancy. A greater degree of crowding increases the chances of treatment involving a reduction in dental mass.^{15,17}

Correction of crowding in the mixed dentition through tooth reduction is achieved through a serial extraction.^{4,6,7,16} As its name suggests, serial extraction is the correction of mixed dentition crowding through the strategically programmed

extraction of deciduous and permanent teeth (in that order) for the alignment of the remaining teeth (Fig 1) and foresees extractions in two distinct phases. In the first transitory period, the extraction of anterior deciduous teeth is indicated in order to allow the alignment of the permanent incisors, preferably without orthodontic mechanics. The second phase may or may not be performed and coincides with the second transitory period of the mixed dentition. This phase involves the extraction of permanent teeth (generally the first premolars), which aims at correcting the crowding of the posterior segment, canines and premolars.¹⁶





FIGURE 1 - Patient treated with serial extraction orthodontic mechanics. First phase of serial extraction involved extraction of deciduous canines in the first transitory period of mixed dentition. Second phase involved extraction of first premolars in second transitory period. **A)** Profile initial photograph. **B)** Frontal initial photograph. **C, D, E)** Intraoral initial photographs. **F, G)** Occlusal initial views. **H, I)** Occlusal views after deciduous canines extraction. **J, K)** First premolars extracted and fixed orthodontic treatment. **L)** Final profile photograph. **M)** Final frontal photograph. **N, O, P)** Final intraoral photographs with Hawley retainer. **Q, R)** Occlusal final views.

Serial extraction does not necessarily involve the extraction of permanent teeth (Fig 2). Thus, the first extraction phase is known as the reversible phase. The need for the extraction of premolars (nearly always the first premolars) should be assessed after their eruption. In principle, one may deduce that a greater proximity between the permanent lateral incisor and the primary first molar leads to a greater tooth-bone discrepancy and greater likelihood of the extraction of permanent teeth, which is the irreversible phase of serial extraction. In the early mixed dentition

phase, it is not always possible to decide whether or not the premolars will be extracted. Moreover, there is a question as to the percentage of patients that undergo the first serial extraction phase without requiring the extraction of permanent teeth.

The aim of the present study was to determine the percentage of patients initially treated with serial extraction who went through to the irreversible phase (extraction of permanent teeth) and determine possible variables associated to the second phase of treatment.





FIGURE 2 - Patient having undergone only extraction of deciduous teeth (reversible phase). The second phase of the serial extraction program was not performed. The patient used headgear at the end of mixed dentition phase, with partial leveling of permanent dentition. **A)** Profile initial photograph, **B)** Frontal initial photograph, **C, D, E)** Intraoral initial photographs. **F)** Initial upper occlusal view. **G)** Initial lower occlusal view. **H, I)** Occlusal views after deciduous canine extractions. **J, K)** Profile and frontal final photographs. **L, M, N)** Final intraoral photographs. **O, P)** Occlusal final views.

MATERIAL AND METHODS

Material

A retrospective study was carried out involving the orthodontic records of 70 patients (38 males and 32 females) from the archives of the Profis

Preventive and Interceptive Orthodontics Course (Bauru, SP, Brazil). The patients were selected based on the treatment plan. All had an initial treatment plan of serial extraction and had mature permanent dentition (second permanent mo-

lars erupted) at the time the study was conducted. The following were the inclusion criteria: Crowding at the time of diagnosis; no agenesis, with the exception of third molars; absence of interproximal caries that could compromise tooth width or arch length; and orthodontic records with good quality (panoramic radiographs, lateral cephalometric radiographs, plaster models, facial profile photographs). Age of the sample ranged from 8 years and 1 month to 13 years and 11 months.

Methods

The records of the 70 patients were carefully analyzed by a single examiner for the determination of the percentage of patients who completed the irreversible serial extraction phase (extraction of first premolars). For such, the following variables were investigated to determine whether they were associated to the extraction of permanent teeth:

1) Facial pattern in normolateral position:

The patients were classified as having Patterns I, II or III and divided into two groups: Patterns I and II (Group 1) and Pattern III (Group 2). As a non-significant number of patients had the Long Face pattern, these patients were excluded from the facial pattern analysis. No Short Face pattern was found in the sample.

2) Classification of malocclusion in Classes I, II and III based on the relation of primary canines.

3) Position of lower incisors in symphysis:

Quantified on normolateral radiographs by measuring the incisor-mandibular plane angle (IMPA).

4) Proportion between size of lower second permanent molar and retromolar space:

Panoramic radiographs with dates as close as possible to the time of extraction of the first premolars (if indicated) and those corresponding to patients who were not submitted to premolar extraction were selected.

For the measurement of the retromolar space, a horizontal line was drawn from the tip of the

distal cuspid of the permanent first molar to the retromolar space. A perpendicular line was then drawn from this line on the distal tip of the first molar. A ruler was placed over the anterior limit of the ramus of the mandible in such a way as to touch the greatest number of points on this structure and a third line was drawn, representing the anterior limit of the ramus. The retromolar space was measured as the distance between the line drawn on the distal tip of the first permanent molar and the line representing the ramus of the mandible (Fig 3). This measurement was performed on both the right and left sides. The mesiodistal length of the second molar was measured with a ruler, considering the longest distance between the mesial and distal faces of this tooth.

The proportion between the size of the second permanent molar and the retromolar space was determined by dividing the mesiodistal length of the second molar by the retromolar space on both the right and left sides.

The measurements of the IMPA, retromolar space (both on the cephalometric radiograph) and mesiodistal length of the second molar (panoramic radiographs) were performed by a single, calibrated examiner with the aid of an X-ray viewer in a dark room. The tracings of the lines on the panoramic radiographs were performed with a 0.5 mm graphite pencil, ruler and protractor.

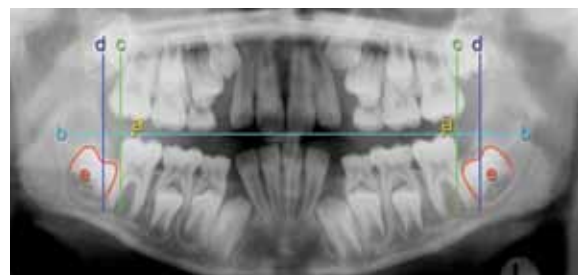


FIGURE 3 - Tracing on panoramic radiograph showing reference lines used to measure retromolar space; (a) tip of distal cusp of first molar; (b) horizontal line drawn from tip of distal cusp of first molar to retromolar space; (c) line perpendicular to horizontal line; (d) line from anterior limit of mandibular ramus; (e) radiographic image of the second permanent molar.

5) Use of orthodontics mechanics during serial extraction:

For this variable, three treatment options received codes from 1 to 3: (1) mechanics for space gain; (2) mechanics for space maintenance; and (3) absence of orthodontic treatment during serial extraction.

6) Model discrepancy:

Model discrepancy was calculated considering existing space and the space required for the accommodation of all teeth. The existing space was calculated considering three segments measured with a digital caliper (Precision Equipment CO, Boston, MA, USA): Mesial of first permanent molar to distal of lateral incisor, right and left sides, and distal to distal of the lateral incisor. The calculation of space required was performed by measuring the width of the lower incisors directly on the model. The estimate of the mesiodistal width of the teeth of the posterior segment was performed using the Tanaka-Johnston formula for the lower arch:¹⁹

$X = (Y/2 + A) \times 2$, where:

- » X is the length of the canines and non-erupted premolars;
- » Y is the width of the four lower incisors;
- » A is the constant for the lower arch (75% probability) equal to 10.5 mm.

Statistical analysis

Fisher's exact test was used to determine associations between premolar extraction and each of the categorical variables (univariate analysis).¹ A logistic regression model was used for the numeric variables.¹⁰

RESULTS

Seventy percent of the patients with serial extraction in the initial treatment plan required the complete treatment with extraction of premolars. The other 30% only required the reversible phase of the program (extraction of deciduous teeth only). There were no statistically significant

associations between the need for the extraction of permanent teeth and the variables studied, with the exception of model discrepancy in the posterior segment (Tables 1 and 2; Fig 4). Due to the absence of some models for the analysis, only 57 patients were assessed for the calculation of model discrepancy. If the initial mean model discrepancy was greater than -6.69 mm (Table 2), the patient was expected to require the extraction of premolars in the serial extraction.

DISCUSSION

The early extraction of deciduous lateral incisors and canines and subsequent extraction of first premolars favors the spontaneous alignment of the other teeth in the alveolar crest in the period of mixed dentition.²¹ This simplifies the corrective mechanics for the permanent dentition and is the principle of serial extraction.^{7,16} At times, corrective orthodontics is not even necessary for the finishing of the case.

The total duration of treatment is significantly greater for patients who undergo serial extraction, considering the number of appointments and time in which the development of the occlusion is followed.²⁰ However, the advantages are related to the self-esteem of children who see their teeth aligned at an early age, with the periodontal condition of teeth erupting spontaneously in the center of the alveolar ridge.

In the present sample, 70% of the patients indicated for serial extraction continued through to premolar extraction, whereas the other 30% only underwent the first phase of the treatment (extraction of deciduous teeth). A number of variables were investigated to determine likely factors that influenced premolar extraction.

Crowding is manifested independently from the sagittal condition between bone bases, and the skeletal pattern affects how an orthodontist considers the crowding, with lower crowding occurring more in patients with a Pattern II face and upper crowding occurring more in those with Pattern III, at least

TABLE 1 - Distribution of patients in need of extraction of deciduous teeth (reversible phase) and permanent teeth (irreversible phase) according to facial pattern, occlusion classification, IMPA, proportion of second permanent molar/retromolar space and orthodontic mechanics.

Variable (Statistical Analysis)	Treatment phase				Total	(%)	p value
	Irreversible	(%)	Reversible	(%)			
Facial Pattern (Fisher's Exact Test)							
I and II	44	(69)	20	(31)	64	(100)	p=0.6607
III	5	(83)	1	(17)	6	(100)	
Total	49	(70)	21	(30)	70	(100)	
Classification (Fisher's Exact Test)							
I	25	(69)	11	(31)	36	(100)	p=1.000
II	22	(69)	10	(31)	32	(100)	
III	2	(100)	-	-	2	(100)	
Total	49	(70)	21	(30)	70	(100)	
IMPA (Simple Regression Logistic)							
< 80	8	(73)	3	(27)	11	(100)	p=0.1221
80 --- 90	25	(81)	6	(19)	31	(100)	
> 90	16	(57)	12	(43)	28	(100)	
Total	49	(70)	21	(30)	70	(100)	
Proportion second permanent molar/left retromolar space (Simple Regression Logistic)							
< 1	12	(60)	8	(40)	20	(100)	p=0.677
1 --- 1.4	27	(79)	7	(21)	34	(100)	
1.4 or +	10	(63)	6	(38)	16	(100)	
Total	49	(70)	21	(30)	70	(100)	
Proportion second permanent molar/left retromolar space (Simple Regression Logistic)							
< 1	15	(65)	8	(35)	23	(100)	p=0.540
1 --- 1.4	24	(73)	9	(27)	33	(100)	
1.4 or +	10	(71)	4	(29)	14	(100)	
Total	49	(70)	21	(30)	70	(100)	
Used Mechanics (Fisher's Exact Test)							
(1) Space Gain	28	(62)	17	(38)	45	(100)	p=0.079
(2) Space Maintainance	8	(100)	-	-	8	(100)	
(3) Absence of Orthodontic Treatment during SEP	13	(76)	4	(24)	17	(100)	
Total	49	(70)	21	(30)	70	(100)	

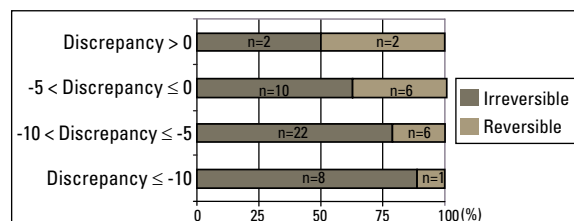


FIGURE 4 - Magnitude of model discrepancy between groups with premolar extraction (irreversible phase) and non-extraction (reversible phase).

TABLE 2 - Mean and standard deviation of tooth-arch size discrepancy in both groups of patients.

	N	Mean	Standard Deviation
Irreversible	42	-6.69	3.44
Reversible	15	-3.58	5.16
Total	57	-5.87	4.15

p=0.02* (Logistic Regression Model).

in compensatory treatment. It is expected that patients with Pattern II would extract fewer lower teeth in relation to patients with Pattern III in order to compensate for the malocclusion and not further increase overjet. For this reason, facial pattern was studied in the present investigation.

Curiously, the sagittal relationship of the dental arches had no statistically significant influence over the decision to extract premolars. It is likely that facial pattern is more decisive in borderline cases in which there is a deadlock in the second phase serial extraction. With Pattern II accompanied by Class II, Division 1 malocclusion, one must also consider the atresia of the upper dental arch, which can be expanded, especially in treatment involving the orthopedic advancement of the mandible.¹⁸ In the present study, patients with Patterns I and II were grouped together for the statistical analysis and there was a small number of patients with Pattern III (n=6). A study with a broader sample involving the three facial patterns may identify differences in the prevalence of premolar extractions during serial extraction.

Despite the statistically significant result reported here, the treatment for malocclusions is planned for each patient individually based on specific morphological characteristics.¹³ An incorrect planning, with teeth extractions, could result in an unpleasing facial profile, affecting the esthetics of both the smile and face.¹² In the present study, there were no statistically significant differences in relation to malocclusion class between patients who only underwent the first phase of serial extraction and those who went through to the irreversible phase.

There was no significant association between protrusion of the lower incisors (assessed here by the IMPA) and the need for premolar extraction, even considering that protruded profiles are more favorable to tooth extraction.¹² Patients with an IMPA > 90° were evenly distributed between the reversible phase (43%) and irreversible phase (57%). From the facial profile analysis, none of

the patients were considered to exhibit bimaxillary protrusion. It is possible that the protrusion identified in this analysis is more associated to candidates for tooth extraction than the analysis of IMPA alone.

The assessment of the retromolar spaces is important in treatment planning with the aim of having erupted permanent second molars in occlusion. In the present study, the proportion between the size of the second permanent molar and retromolar space did not have a statistically significant association with the decision to extract the premolars (Table 1). It is likely that the analysis of the retromolar space acquires importance in individual planning. In borderline cases, in which there is a risk of impaction of a second molar through the use of a lip bumper due to the limitation of the retromolar space, extraction is the best treatment option.

Appliances such as a Haas expander for the upper arch and a lip bumper for the lower arch are indicated for the definite correction of crowding when the arch is atretic. These appliances provide a more adequate morphology for the dental arches as well as space for the alignment of the teeth. The Nance lingual arch can preserve space in the posterior segment that would otherwise be spontaneously lost with the alignment of the erupting permanent teeth. The Leeway space, together with the dimensional alterations of the mixed dentition, helps to provide space to resolve crowding in the mixed dentition.^{8,9} In a study involving 107 patients with crowding of the lower incisors, the Nance lingual arch proved to be effective in maintaining the length of the arch during the transition from the mixed to the permanent dentition.⁵ Following treatment with the lingual arch, the space for alleviating the crowding proved to be sufficient in 60% of patients who had mean crowding of 4.85 mm prior to treatment.

For cases of severe crowding in the mixed dentition, the expansion approach has currently given way to serial extraction.¹⁷ In borderline

cases, appliances may be indicated to preserve or gain space. An orthodontist may encounter atretic dental arches even in cases of severe crowding, which suggests the need for transversal mechanics despite tooth extraction. For this reason, the presence of orthodontic mechanics jointly with serial extraction was investigated on the patient records. The results reveal that the use of appliances had no influence over the decision regarding premolar extraction.

Tooth-arch size discrepancy (degree of initial crowding) was the only variable with a statistically significant correlation to premolar extraction. Thus, identifying the amount of error in the intra-arch relation is the primary aspect in the planning for serial extraction. The mean discrepancy for the group that underwent premolar extraction was -6.69 mm, whereas the discrepancy in the group that only underwent the first phase of serial extraction was -3.58 mm, as determined by the Tanaka-Johnston¹⁹ formula for estimating the mesiodistal width of the teeth in the posterior segment. This difference was statistically significant ($p = 0.02$). Thus, a greater initial tooth-arch size discrepancy signifies a greater chance of undergoing the irreversible phase of serial extraction (Table 2). The literature reports that patients

treated with premolar extraction exhibit greater tooth-bone discrepancy.³ Thus, as demonstrated by the present investigation and previous studies, the degree of tooth-bone discrepancy seems to be a factor of considerable clinical importance (although not the only factor) to the decision as to whether to extract the premolars.^{2,3,11}

CONCLUSIONS

The majority of patients (70%) with an initial plan for serial extraction to resolve crowding completed the entire procedure with the extraction of permanent teeth.

Facial pattern, sagittal relation between the dental arches, IMPA, proportion of second permanent molar/retromolar space and orthodontic treatment during serial extraction had no statistically significant association to the need for premolar extraction.

The tooth-arch size discrepancy (degree of crowding) was significantly associated to the need for premolar extraction ($p=0.02$).

The mean discrepancy was -6.69 mm in the group that underwent premolar extraction and -3.58 mm in the group that only underwent the first phase of serial extraction (only extraction of primary teeth).

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Effects evaluation of remaining resin removal (three modes) on enamel surface after bracket debonding

Karine Macieski*, Roberto Rocha**, Arno Locks***, Gerson Ulema Ribeiro****

Abstract

Introduction: An appropriate selection of instruments is essential to perform a correct debonding technique, by properly removing orthodontic brackets and the remaining resin. **Objective:** The aim of this study was to evaluate three methods of remaining resin removal on enamel surface after bracket debonding, by means of Scanning Electron Microscopy (SEM). **Methods:** Eighteen bovine incisors were selected and divided into three groups (A, B and C) of six teeth each. Before bracket bonding, epoxy resin casts were obtained by impression of the teeth with addition silicon, in order to register baseline enamel characteristics and representing the control group. The methods for remaining resin removal were: Group A – gross and medium granulation Soflex discs; Group B – carbide bur in low-speed; Group C – carbide bur in high-speed. Soflex polishing system fine and ultrafine granulation discs were used for Group A, rubber tips for Groups B and C, and polishing paste for all groups. After polishing, impression of teeth were taken and casts were analyzed by means of SEM. The baseline enamel characteristics (Control Group) were compared to the final aspect of enamel to determine the method that generated less enamel abrasion. **Results and Conclusion:** The remaining resin removal by carbide bur in low-rotation, and enamel polished with rubber tips followed by polishing paste produced the smaller damage to the enamel.

Keywords: Dental enamel. Bracket. Debonding.

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INTRODUCTION

In the past, the fixation of orthodontic accessories was performed by banding all involved teeth. This procedure resulted in greater complexity and delay from the clinical aspect, compromised esthetics, patient discomfort, increased arch perimeter, among other disadvantages. Great changes occurred in clinical orthodontic with the establishment of the enamel acid etching technique by Buonocore⁵ in 1955, allowing direct bonding of orthodontic brackets to dental surface.

Several studies were conducted for the development of adhesive materials that would fulfill the clinical requirements according to their physicochemical and mechanical properties. Recently, materials that present better bonding characteristics are composite resins, which present greater bond strength values to enamel, and the resin modified glass-ionomer cements, which chemically adhere to dental structures and also release fluoride to the oral environment.²⁴

Although there are several advantages for direct bracket bonding, some disadvantages are also observed, including damage to enamel surface during bonding and mainly when removing brackets and the remaining resin. Enamel damage may be related to the use of abrasive prophylaxis,²¹ acid etching,^{12,13,15,21} excessive strength during bracket removal resulting in enamel fractures,²⁷ or to the mechanical removal of resin with rotary instruments.^{9,12,21,25}

Thus, the ideal debonding method should remove the bracket and all remaining adhesive, resulting in minimal enamel surface alterations. Adequate instruments selection for brackets removal and for remaining resin removal, and also the type of adhesive are fundamental.²⁸

Several studies^{4,6,10,12,16,22,26} report different techniques for removing remaining resin and their effects on enamel surface. Reported procedures and instruments include: Pliers,^{11,12,21,22,23} carbide burs in high or low speed,^{6,9,12,13,21,22,23,25,26,28} polishing discs,^{12,26,28} polishing paste or pumice,^{23,26,28}

as well as the ultrasound.^{13,16} All techniques lead to different polishing degrees, abrasions and scratches incidence, and consequent damage to enamel surface.

The aim of the present study was to evaluate the enamel surface by means of Scanning Electron Microscopy (SEM), after using three different methods for remaining resin removal after bracket debonding. Baseline enamel characteristics (Control Group) were compared with possible enamel variations after resin removal, determining the method that generated less damage to enamel surface.

MATERIAL AND METHODS

Eighteen bovine incisors, presenting no visible fractures or cracks to naked eye were selected. They were stored in a 0.5% thymol solution at room temperature. Teeth were randomly divided into three groups (A, B and C) of six teeth each.

Roots were separated from the crowns at the cement-enamel junction. Crowns were positioned in polyvinyl chloride (PVC) cylinders, fixed by their lingual surface with self-cured acrylic resin.

A marking with two perpendicular line segments (Fig 1) was made with double sided diamond discs (KG-Sorensen), guiding brackets placement (Fig 2) and allowing further SEM analysis at the same enamel area.

The specimens received prophylaxis with rubber cups (Microdont) and pumice (SS White – Extra-fine). Impressions with addition silicon were performed (Express, 3M ESPE) and epoxy resin casts obtained (Fig 3). The epoxy resin casts replicated enamel surface prior to bracket placement (Fig 4) with no damage and thus, represented the Control Group. New impressions of specimens were made after each procedure of remaining resin removal. New epoxy resin casts were obtained to determine the effects of each procedure on enamel surface in comparison to the baseline data.



FIGURE 1 - Fabrication of a guide for bracket bonding.



FIGURE 2 - Guide marking for bracket bonding.



FIGURE 3 - Impression with addition silicon and epoxy resin.

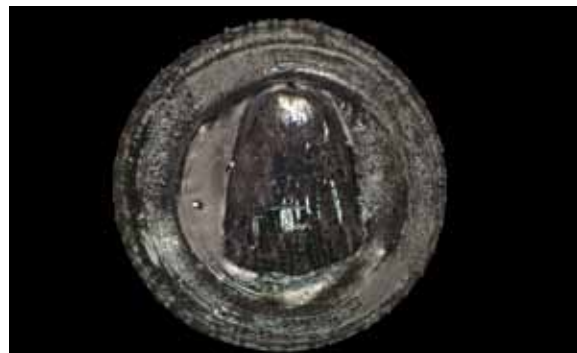


FIGURE 4 - Dental cast in epoxy resin prior to bracket placement – Control group.

Edgewise brackets 0.022 x 0.028-in slot (Morelli) for maxillary lateral incisors and direct bonding were employed. Enamel was etched with 37% phosphoric acid for 15 seconds. Transbond XT Light Cure Adhesive (3M Unitek) was used for the adhesive procedure.^{2,3} Composite resin was placed at the brackets base and pushed toward dental surface. The brackets edges followed the marking guides and excess composite resin was removed.

Composite resin was light activated following the manufacturers' instructions. The specimens were store in distilled water at room temperature for 7 days, up to complete composite resin setting and prior to brackets removal.⁷

Brackets were removed with the aid of an Ortho-pli band plier, with pressure at the bracket wing, perpendicularly to the slot orientation.

Tested methods of remaining resin removal

» Group A: Soflex (3M ESPE), gross and medium granulation discs, used with low pressure for remaining adhesive removal; and fine and ultra fine granulations for 20 seconds for each polishing procedure (Fig 5) were employed. Final polishing was performed with the polishing paste Enamelize – Cosmedent (Fig 6), applied with felt discs for 20 seconds.

» Group B: TP Orthodontics #100-122 carbide debonding bur in low-speed (Fig 7), used in



FIGURE 5 - Soflex discs – gross, medium, fine and ultra fine granulation (3M ESPE).



FIGURE 6 - Polishing paste for enamel - Enamelize (Cosmedent) and felt discs.



FIGURE 7 - TP Orthodontics #100-122 carbide debonding bur.



FIGURE 8 - Rubber point sequence 557626 Astropol (Ivoclar-Vivadent).

unidirectional movements; followed by polishing with abrasive impregnated silicon burs 557626 Astropol (Ivoclar-Vivadent) in low-speed for 20 seconds (Fig 8) were used. Final polishing was performed with the polishing paste Enamelize (Cosmedent) applied with felt discs for 20 seconds.

» Group C: TP Orthodontics #100-121 carbide debonding bur in high speed (Fig 9) was used in unidirectional movements; followed by impregnated silicon burs – 557626 Astropol (Ivoclar-Vivadent) – in low speed for 20 seconds for each point. Final polishing was performed with the polishing paste Enamelize (Cosmedent), applied with felt discs for similar time.

The visual assessment of remaining adhesive removal was performed under direct visual assessment with the aid of dental chair light and explorer, to simulate the clinical conditions.

The epoxy resin casts were covered with 3 μm layer of palladium and gold (Fig 10). They were evaluated by scanning electron microscopy (Philips XL 30) (Fig 11), with 40X magnification and 20 kv acceleration voltage. The photomicrographs were evaluated by a single evaluator, through visual comparison of the enamel characteristics prior (Control Group) and after the finishing procedures for remaining resin removal. This allowed assessing changes forced on enamel surface on each tested group in comparison to the images obtained at baseline (Control Group).



FIGURE 9 - TP Orthodontics #100-121 carbide debonding bur.



FIGURE 10 - Epoxy resin cast covered with palladium and gold.

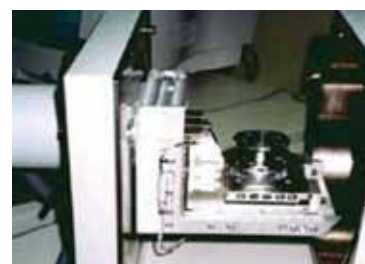


FIGURE 11 - Scanning Electron Microscope.

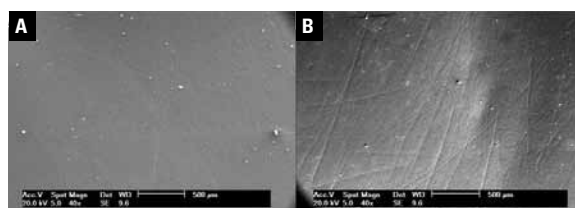


FIGURE 12 - Enamel characteristics variation prior to bracket bonding – Control group.

RESULTS

Large variation on the original enamel characteristics of each evaluated tooth was detected (Control Group) (Fig 12). For this reason, the replication of teeth with epoxy resin prior to orthodontic bracket bonding was essential, and the comparison between original enamel characteristics and characteristics after bonding, debonding and final polishing was possible.

All tested protocols efficiently removed the remaining resin, evaluated by visual assessment and by SEM, but led to irreversible changes on enamel surface.

For Group A, Soflex gross and medium granulation discs were able to remove resin, but with higher difficulty in comparison to the other tested methods. The photomicrographs revealed great number of scratches (Fig 13B) in comparison to the Control Group (Fig 13A). Scratches were softened by polishing with the sequence of fine and ultra fine discs (Fig 13C) and the polishing paste (Fig 13D). Well polished enamel surfaces were microscopically observed after using the sequence of discs. However, great changes on

enamel topography with surface flattening were also present. The remaining resin removal and polishing consequently relied on enamel removal.

Carbide bur in low speed, in Group B, efficiently removed remaining resin, generating light and fine striae on dental surface (Fig 14B), and preserving the baseline enamel characteristics (Fig 14A). Striae were softened by employing the silicon points' sequence, resulting in efficient enamel polishing (Fig 14C). The polishing paste removed light abrasions, propitiating a microscopically good enamel surface (Fig 14D). This procedure resulted in lower detectable enamel loss compared to the other tested procedures, and enamel topography remained closer to the baseline observation.

For Group C, carbide bur in high speed easily removed remaining resin. However, even when used with proper care, it produced a large number of moderate striae on enamel surface under microscopic evaluation (Fig 15B), resulting in a difficult control of enamel loss. The silicon points sequence employment was efficient for enamel polishing, softening the abrasive marks promoted by carbide debonding burs (Fig 15C), although not being able to completely remove them. The polishing paste was able to further reduce striae formed during carbide bur stage (Fig 15D).

All tested polishing agents were efficient in reducing the abrasions that inevitably occur during remaining resin removal. Soflex fine and ultrafine granulation discs considerably removed scratches promoted by coarser discs. The employment of

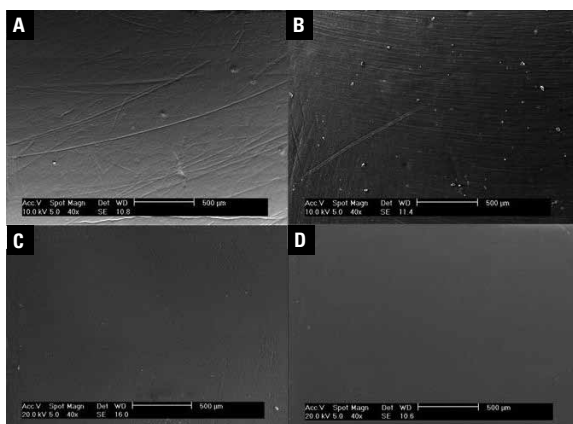


FIGURE 13 - A) Group A photomicrography prior to bracket bonding (control). **B)** After remaining resin removal with Soflex gross and medium granulation discs. Many abrasive marks on dental surface can be observed. **C)** Soflex fine and ultra fine granulation discs polishing. Decreased number of scratches, with the most intense ones still present. **D)** Use of polishing paste. The surface characteristics were improved.

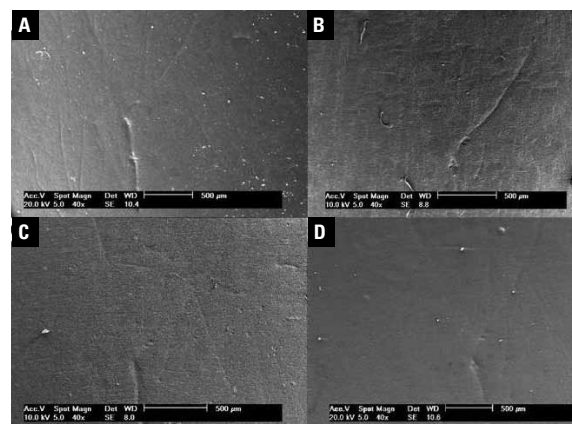


FIGURE 14 - A) Group B photomicrography prior to bracket bonding (control). **B)** After remaining resin removal with debonding burs. Light striae can be observed, with enamel surface characteristics close to baseline observation. **C)** Polishing with the sequence of silicon points. The majority of striae were removed. **D)** Final polishing with polishing paste. Improved surface smoothness was detected.

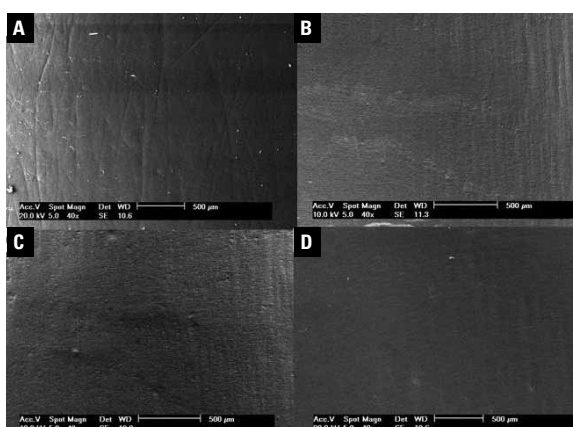


FIGURE 15 - A) Group C photomicrography prior to bracket bonding (control). **B)** After remaining resin removal with carbide bur in high speed. Moderate striae in higher number is detected. **C)** Polishing with the silicon points sequence. This step was efficient for enamel polishing and softening striae, although not being able to completely remove them. **D)** Final polishing with polishing paste. Further reduction of striae produced by carbide burs is observed.

silicon points sequence softened striae promoted by debonding burs. Excellent final polishing results were obtained with the polishing paste, which considerably reduced enamel variations caused by previously used instruments, and therefore important to obtain a smoother enamel surface.

DISCUSSION

All tested methods clearly removed the remaining resin, but irreversible enamel surface alterations were generated. For Group A, the discs sequence produced well polished surfaces, assessed by either a microscope or by naked eye, but on expense of great change on enamel topography and consequently on enamel removal. For Group B, during naked eye assessment, enamel presented glossy appearance after remaining resin removal. This glossy aspect was improved with the whole polishing procedure leading to optimum enamel surfaces. For Group C, enamel presented no glossy appearance, in other words, lower enamel smoothness after the employment of carbide bur in high speed. The glossy appearance was reestablished after the employment of silicon points and polishing paste, leading to a clinically acceptable enamel surface.

Enamel loss during remaining resin removal has been reported in the literature, varying from 27.5 to 48 μm ,⁴ 55.6 μm ,¹⁰ and from 26.1 to 41.2 μm .²¹ This variation is dependent on the quantity of bonding material fillers, being non significant in comparison to enamel mean

thickness of 1,500 to 2,000 μm .⁴ The quantity of enamel loss during debonding procedures becomes clinically significant considering that higher fluoride concentration is present at enamel outer surfaces and decreases considerably after the first 20 μm .⁴ The employment of conservative instruments and techniques is thus important, once multiple bonding procedures reaching this depth should be considered.

Instruments used for resin removal must keep the majority of dental enamel topographic characteristics, due to dental tissues health and esthetics. Inadequate procedures may remove enamel and alter the original tooth morphology, creating depressions, facets and fractures,^{4,11,14,25} which may lead to areas of decalcification and thus, possible cavitated carious lesions.^{1,8,9,16,19} Incomplete resin removal facilitates dental plaque accumulation and compromise esthetics due to color variations of remaining resin, which might occur by bacterial activity or food dye impregnation.^{8,9,16,19}

Although there is a 21 to 44% bond strength reduction in permanent or primary bovine enamel, the employment of bovine teeth represents a viable solution for adhesion studies. This reduction is related to faster bovine teeth development, the presence of greater surface irregularities and larger enamel crystals.¹⁷ On the other hand, the advantages of being similar to human enamel and easy acquisition surpass their disadvantages.

Several studies^{6,8,10,11,16,18,22,23,25,26,28} revealed SEM and epoxy resin casts as presenting good characteristics for evaluating enamel morphology changes after different procedures for bracket debonding and surface polishing. Great variation on enamel characteristics was detected for each presently evaluated tooth, similarly as reported by Zarrinia, Eid and Kehoe.²⁸ For this reason, resin epoxy casts were necessary prior to bracket bonding to allow higher accuracy of the comparative analyses among the effects of performed procedures on dental enamel.

The remaining adhesive removal with gross and medium granulation Soflex discs was effi-

cient, but occurred more difficultly and caused enamel surface flattening with consequent enamel loss. The same observations were detected by Campbell⁶ and Zarrinia, Eid e Kehoe.²⁸ Zachrisson and Artun,²⁶ and Gwinnet and Gorelick,¹¹ in contradiction to the present results, considered this method inefficient, with remaining resin left on enamel surface.

Tungsten carbide burs in both low^{1,6,12,15,17} or high speed^{6,9,22,23,28} have been the most indicated instrument for remaining resin removal. However, during the comparison of this bur in both speeds during remaining resin removal, Rouleau, Marshall and Cooley²³ observed better results when using high speed, while other studies^{12,13,21} detected better results for low speed. Better results were also detected in the present study for the use of carbide bur in low speed, being more conservative for enamel.

All tested polishing agents were efficient for decreasing striae and scratches, which inevitably occur during remaining resin removal, propitiating enamel surface smoothness. Soflex fine and ultrafine granulation discs considerably reduced scratches resulted by coarser discs, as detected in other reports.^{11,22,28} In agreement with other studies,^{6,22} the silicon points sequence softened striae resulting from carbide burs in low and high speed, leading to a glossier and smoother surface.

Similarly to the present study, the final polishing with polishing paste or pumice is considered an essential step to reduce abrasive marks produced by instruments during debonding and remaining adhesive removal.^{4,6,11,16,22,26,28} The use of polishing paste in all tested groups clinically improved the gloss aspect, and microscopically provided a smoother enamel surface.

The aspect of enamel surface after debonding should be compared to adjacent surfaces. It is important for this assessment to evaluate enamel in dry and wet conditions, once reflection and refraction phenomena associated with wet surfaces may hide irregularities.¹¹

Further studies might enhance the knowledge about the quantity of enamel loss and the depth of abrasive marks.

CONCLUSIONS

- » All tested methods for remaining resin removal generated changes in the enamel surface.
- » The tested procedures efficiently removed the remaining resin. Soflex discs presented the highest removal difficulty, while carbide bur the easiest. But this last led to more abrasive marks production.
- » Carbide bur in low speed generates light striae on dental surface. However, it maintains the enamel surface characteristics similar to the characteristics prior to the bracket bonding, leading to fewer variations in comparison to the other tested methods.
- » All tested polishing agents were efficient to reduce abrasive marks, being indispensable to achieve smoother enamel surfaces.
- » The remaining adhesive removal performed with carbide debonding bur in low speed, silicon points polishing and final polishing with polishing paste is the procedure that results in less damages to enamel surface, being the choice sequence of procedures for remaining resin removal.

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Comparative assessment of anterior spacing in Japanese-Brazilian and Caucasian children in the deciduous dentition

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Abstract

Objective: To carry out a comparative evaluation of prevalence of anterior spacing characteristics in Japanese-Brazilian and Caucasian children in the deciduous dentition. **Methods:** Two samples of children aged 2-6 years were selected: 405 Japanese-Brazilians from 36 schools in the State of São Paulo and 510 Caucasian children from 11 public institutions in São Paulo city. Spacing features in the maxillary and mandibular arches were assigned to four categories: Generalized spacing, only primate spaces, no spacing and crowding. Logistic regression was used to analyze the effect of age, gender and ethnic group on the prevalence of the occlusal characteristics ($\alpha = 0.05$). **Results:** In Japanese-Brazilians, generalized spacing was the most prevalent characteristic in the maxillary (46.2%) and mandibular (53.3%) arches. The frequency of primate spaces was higher in the maxillary arch (28.2% versus 15.3%). Concerning no spacing (21.7% – 26.4%) and crowding (4% – 4.9%), the variation between arches was relatively small. In Caucasian children, no spacing and exclusive presence of primate spaces showed distributions similar to that observed in Japanese-Brazilians. Generalized spacing was diagnosed in approximately 50% of the arches. Crowding prevalence was higher in the mandibular arch (12.8% versus 3.9%). The regression model adjusted for crowding prevalence was the only significant one. Only the ethnical factor was significant ($p < 0.001$). **Conclusions:** It may be suggested that anterior spacing features in the deciduous dentition would not be influenced by age or gender. Nevertheless, Caucasian children would have 2.8 times more chances of presenting crowding in the mandibular arch, in comparison with Japanese-Brazilians.

Keywords: Dental occlusion. Diastema. Deciduous dentition.

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INTRODUCTION

Concerning the deciduous dentition, generalized spacing in the anterior region is the most common characteristic^{1,2,4,9,10,12,15} and is accepted by some authors as favorable for the alignment of permanent anterior teeth.^{3,4,8,15} On the other hand, the presence of proximal contacts or even crowding is not a definitive predictor of malocclusions due to lack of space in the permanent dentition.^{5,20,21} However, some authors²⁴ explain that crowding constitutes a problem not only from an orthodontic point of view, but also because it predisposes to greater retention of dental plaque. A study¹⁶ has mentioned that the crowding of deciduous incisors is probably followed by crowding of permanent incisors and advocated that this characteristic should be considered a malocclusion. Furthermore, even though growth and development cause dimensional and cephalometric changes between the deciduous and permanent dentitions, some children may deviate from the normal pattern.²⁰ Thus, it may be assumed that the follow-up of children with crowding in the deciduous dentition up to the permanent dentition would be a method of Preventive Orthodontics.

Several studies have been conducted on Brazilian children in order to determine the prevalence of anterior spacing characteristics in the deciduous dentition,^{6,7,9,20-23} yet few studies have addressed populations of Japanese-Brazilian individuals. Notably, other occlusal characteristics have also been analyzed, including the association with non-nutritive sucking habits.¹¹ Nonetheless, the anterior spacing has not yet been studied in detail in this population. Considering that ethnicity may influence the occlusal pattern, this study was conducted to comparatively evaluate the prevalence of anterior spacing characteristics in the deciduous dentition in Japanese-Brazilian and Caucasian Brazilian children.

MATERIAL AND METHODS

This cross-sectional epidemiological study was conducted in accordance with the rules and guidelines foreseen in the Resolution 196/96 of the Brazilian Ministry of Health, and was approved by the Committee of Ethics in Researches of University of São Paulo City (UNICID) under protocol No. 13259823.

Study groups

The sample of Japanese-Brazilians comprised 405 healthy children of both genders (203 females and 202 males), aged 2 to 6 years, registered at 36 primary education schools directed to the Japanese community in different cities in the State of São Paulo: Arujá, Bastos, Botucatu, Campinas, Ibiúna, Marília, Mogi das Cruzes, São Paulo and Suzano. The children were considered to be Japanese-Brazilians if they were born in Brazil and presented at least 50% of direct Japanese ancestry, i.e. they should have at least one parent, two grandparents or four great grandparents, either maternal or paternal, born in Japan. Despite the possibility of miscegenation in the group of Japanese-Brazilian children, this was not an exclusion criterion if the 50% of direct Japanese ancestry could be checked. The children's ancestry was analyzed by a genealogical survey, evaluating the nationalities of their parents, grandparents and great grandparents. It was observed that nearly 70% of the children did not have a mixed ancestry, i.e. they had 100% of direct Japanese ancestry. This sample was divided into two age groups: 2-4 years (n = 257) and 5-6 years (n = 148).

The sample of 510 Caucasian Brazilian children, presumably healthy, of both genders (265 females and 245 males), aged 2 to 6 years, was selected from a total of 1,377 children attending six primary education schools run by the municipality and five nursery centers at the Eastern region of São Paulo city. This sample was also divided into two age groups: 2-4 years

(n = 240) and 5-6 years (n = 270). Selection of these children for comparison with the Japanese-Brazilians was based on studies in which Caucasian individuals were evaluated as target population or comparison sample.^{3,14,17,20,21} It should be highlighted that, even though the sample of Caucasian children presented ethnic miscegenation, it was selected because this group had a reasonable number of individuals and presents one ethnic characteristic in common, namely the white color of the skin.

Assessment of occlusal characteristics

Before onset of clinical examinations, the study comprised training of five examiners. This training included two occlusal assessments of 24 children, with a 15-day interval between evaluations. This procedure was conducted on preschool children in one of the schools selected, at the school environment, to simulate the conditions of the epidemiological survey. The intra-examiner agreement was analyzed by the Kappa statistics (κ coefficients from 0.76 to 1.00). Spearman correlation tests were also applied to evaluate the consistency of diagnoses performed by the examiners, analyzed two by two, during the clinical examinations ($R_s > 0.90$).

All children were examined at their school environment, comfortably seated under an artificial light source. Visual inspection of the dental arches was performed with the aid of disposable tongue depressors to retract the soft tissues, in both maximum intercuspation and maximum opening positions.

The maxillary and mandibular dental arches were separately classified in four categories, according to the anterior spacing characteristics:⁹

- **Generalized spacing:** The anterior teeth presented generalized interproximal spaces, including the primate spaces bilaterally. In case of doubt, the examiner considered that the maxillary and mandibular arches should

present at least four and six spaces, respectively, to be included in this category.

- **Only primate spaces:** These arches presented visibly perceptible spaces bilaterally between the maxillary deciduous lateral incisors and canines, as well as between the mandibular deciduous canines and first molars.

- **No spacing:** The anterior teeth presented proximal contacts. In these arches, there was absence of interincisors and primate spaces, bilaterally.

- **Crowding:** In addition to the absence of interproximal spaces, one or more deciduous teeth were deviated in buccal and/or lingual direction in relation to their respective alveolar processes.

Children included in the study groups met the following criteria:

- » Free and informed consent forms signed by the parents/caretakers.
- » Complete deciduous dentition, without erupted or erupting permanent teeth.
- » Absence of extensive carious lesions, crown destructions or proximal restorations that might alter the mesiodistal width of the teeth.
- » Absence of early loss of deciduous teeth.
- » Absence of dental anomalies of shape, number, structure and eruption.
- » Absence of syndromes or cleft lip and palate.
- » No previous orthodontic treatment and/or speech therapy.

Statistical analyses

The relative frequencies of the occlusal characteristics assessed, according to age and gender, for each ethnic group, were plotted and comparatively analyzed by the chi-square test with Bonferroni correction. Thereafter, the effect of age group (2-4 years and 5-6 years), gender (male and female) and ethnic group (Caucasian and Japanese-Brazilian) on the prevalence of each characteristic related to

anterior spacing in the maxillary and mandibular arches was analyzed using adjusted logistic regression models ($\alpha = 5\%$).

RESULTS

Figures 1 and 2 present the distribution of the characteristics analyzed in the maxillary and mandibular arches, respectively, for Japanese-Brazilian and Caucasian children. Generalized spacing was the most prevalent characteristic in Japanese-Brazilians. It should be highlighted that primate spaces were more frequent in the maxillary arch compared to the mandibular arch. The prevalence of crowding was very similar in both arches, ranging from 4% to 4.9%. Generalized spacing was also the most prevalent characteristic in Caucasian children. Once again, the primate spaces were more frequent in the maxillary arch compared

to the mandibular arch. However, the prevalence of crowding was higher in the mandibular arch (12.8% compared to 3.9%).

Analysis of each characteristic separately in the maxillary and mandibular arches revealed no significant differences between age groups and genders, both for Japanese-Brazilian and Caucasian children.

Anterior spacing characteristics were analyzed in the maxillary and mandibular arches using logistic regression models. The factors analyzed included age range, gender and ethnic group. The only model presenting a significant factor was that adjusted for the prevalence of crowding in the mandibular arch. Only the ethnic factor was significant ($p < 0.001$). As demonstrated in Tables 1 and 2, Caucasian children presented a 2.81 times greater chance of developing crowding in the mandibular arch compared to Japanese-Brazilians.

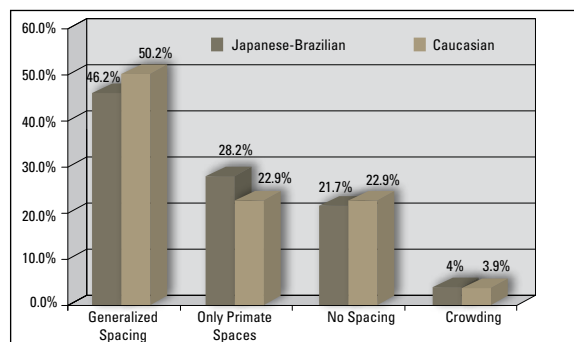


FIGURE 1 - Prevalence of anterior spacing characteristics in the maxillary arch among Japanese-Brazilian and Caucasian children.

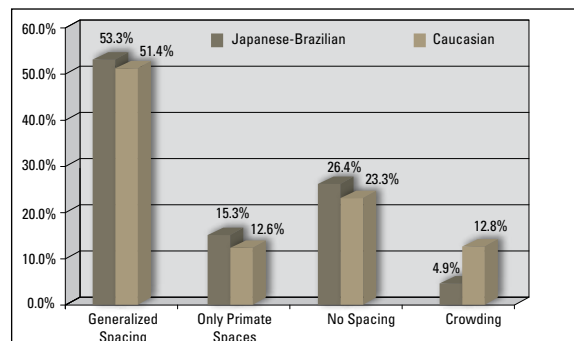


FIGURE 2 - Prevalence of anterior spacing characteristics in the mandibular arch among Japanese-Brazilian and Caucasian children.

TABLE 1 - Logistic regression model for the prevalence of crowding in the mandibular arch.

Factors	Crowding		Logistic Regression		p-value
	no	yes	OR	(CI 95%)	
	n	%	n	%	
2-4 years	459	92.4	38	7.6	
5-6 years	371	88.8	47	11.2	1.33 (0.84; 2.09) 0.227
male	408	91.3	39	8.7	
female	422	90.2	46	9.8	1.11 (0.71; 1.75) 0.640
Caucasian	445	87.3	65	12.7	
Japanese-Brazilian	385	95.1	20	4.9	0.37 (0.22; 0.63) 0.000**

OR = odds ratio. ** = $p < 0.001$.

TABLE 2 - Logistic regression model for the prevalence of crowding in the mandibular arch, considering only the ethnic groups.

Ethnic Group	Crowding		Logistic Regression		p-value
	no	yes	OR	(CI 95%)	
	n	%	n	%	
Japanese-Brazilian	385	95.1	20	4.9	
Caucasian	445	87.3	65	12.7	2.81 (1.67; 4.72) 0.000**

OR = odds ratio. ** = $p < 0.001$.

DISCUSSION

Assessment of the occlusal patterns in different ethnic groups is relevant and also very useful from a clinical point of view. Several Brazilian and international authors have conducted comparative investigations on the occlusal characteristics in the deciduous dentition. A study conducted in the 90's¹⁴ revealed that children of African descent presented significantly less crowding compared to Finnish children, of Caucasian descent. This observation was corroborated later.³ Considering data from a single country with marked ethnic traits, it is interesting to mention the study that evaluated children of the three major ethnic groups in Nigeria (Yoruba, Ibo and Hausa).¹⁸ Spacing was more frequent among children of Ibo ethnicity (48.4%) and less frequently observed in Hausa children (19.8%), $p < 0.001$. The distribution of primate spaces bilaterally also evidenced significant differences for the mandibular arch, being more prevalent in Ibo children (49.4%) compared to Hausa (21.3%) and Yoruba children (29.3%), $p < 0.001$.

Most people of Japanese descent live in the State of São Paulo, accounting for nearly 76% of all such individuals in Brazil.¹¹ This high indicator justifies the accomplishment of comparative epidemiological studies on these people, who are called Japanese-Brazilians because they were born in Brazil and have strong Japanese genetic inheritance (at least 50% of direct ancestry).

Investigation of the occlusal characteristics in Japanese-Brazilians has already been conducted. However, no studies had addressed the anterior spacing in the deciduous dentition in this population. Moreover, if the anterior spacing was not an important aspect of occlusion, there would not be classical^{4,10,17} and contemporary studies^{3,9,18} on this subject.

In the present study, generalized spacing was the most prevalent characteristic both in Japanese-Brazilian and Caucasian children.

These findings are in agreement with the results of other studies.^{1,4,8,9,13,19,22} However, the reports evidence a noticeable variability, from 86.65%²² to 37.7%¹⁹ in the maxillary arch; and from 79.96% to 44% in the mandibular arch, according to the same scientific investigations. A study conducted on Egyptian children⁸ reported similar results as those observed in the present study.

The second most frequent characteristic in the ethnic groups was related to the presence of primate spaces, specifically in the maxillary arch. If the frequency of the exclusive presence of primate spaces is combined to the values obtained for the prevalence of generalized spacing, it may be assumed that the present results agree with several studies that reported prevalence of primate spaces in more than 60% of the samples.^{1,3,6,13,17,19,23} The explanation would lie in the combination of percentage values. The results of this investigation are corroborated by two studies^{8,9} conducted in different countries, which used a similar classification for the diagnosis and observed higher percentage values of this characteristic in the maxillary arch.

The absence of spacing, though less common, is not a sign of abnormality in the deciduous dentition. In this study, the frequency of dental arches with absence of spacing ranged from 21.7% to 26.4% in Japanese-Brazilians and from 22.9% to 23.3% in Caucasian children, with higher percentages for the mandibular arch. Similarly, other authors^{8,10,19} reported greater predominance of absence of spacing in the mandibular arch. The comparison with other studies^{1,2,4,12,19} is impaired by the grouping of two variables: Absence of spacing and crowding. These variables were analyzed individually in the present study, because crowding was considered a deviation from a clinically satisfactory deciduous dentition.^{24,25} Also, there is scientific evidence based on longitudinal studies to advocate the follow-up of children

with crowding in the deciduous dentition as a valid approach, aiming at the detection and early interception of its influence in the mixed and permanent dentitions.^{5,21}

In Caucasian children, as observed in the permanent dentition, the prevalence of crowding was higher in the mandibular arch (12.8% compared to 3.9%). This result is in accordance with the report of a previous study conducted on children having distinct ethnic characteristics.⁹ Interestingly, in the sample of Japanese-Brazilian children, the values relative to the prevalence of crowding were very similar, ranging from 4% in the maxillary arch to 4.9% in the mandibular arch. The difference in the study groups was corroborated by the logistic regression analysis (Tables 1 and 2). Caucasian children presented a 2.8 times greater chance of having crowding in the mandibular arch, compared to Japanese descents.

There was no gender dimorphism for the anterior spacing characteristics in Japanese-Brazilian and Caucasian children. Several other authors have analyzed the aspects related to anterior spacing and also did not observe differences between boys and girls.^{2,6,7,9,22,24} However, other researchers mentioned this type of dimorphism.^{1,3,23} The primate spaces would be significantly wider and more frequently diagnosed in boys compared to girls.^{1,3}

Concerning the possibility of changing the anterior spacing characteristics with the increase in age, the statistical analysis did not demonstrate differences between age groups. A Brazilian study revealed a significant decrease in the number of children with interproximal spacing with the increase in age, suggesting a tendency to space closure.²³ Other study evidenced a significantly reduced frequency of primate spaces at the age range from 4 to 6 years ($p < 0.05$), in comparison to the group of children aged 2 to incomplete 4 years.⁶ An author mentioned that the prevalence of crowding in the anterior region increased with age both in Caucasian children (3-4 years: 5%; 5-6 years: 16%) and those of African descent (3-4 years: 5%; 5-6 years: 9%).¹⁴ However, regarding to crowding, other authors did not find statistically significant difference between age groups.²⁴

Longitudinal studies might allow a more reliable analysis of the changes in anterior spacing with the increase in age. Nevertheless, prospective studies require more time and are subjected to remarkable sample reduction during the follow-up interval. This aspect relative to the logistic demand would be even more unfavorable in a sample of Japanese-Brazilian children, considering that the present study included children from nine different cities in the State of São Paulo.

CONCLUSIONS

- » In the sample of Japanese-Brazilian children, generalized anterior spacing was the most prevalent characteristic in the maxillary and mandibular arches. The frequency of primate spaces was higher in the maxillary arch. However, for the characteristics related to absence of spaces and crowding, there was relatively small variation between percentages calculated for both arches.
- » In the sample of Caucasian Brazilians, the frequencies of characteristics related to absence of interproximal spaces and presence of primate spaces demonstrated similar distributions as observed in Japanese-Brazilians. It should be highlighted that generalized spacing was observed in nearly 50% of the dental arches. However, the prevalence of crowding was higher in the mandibular arch.
- » In both study samples, there was no significant difference between age groups (2-4 years and 5-6 years), nor gender dimorphism.
- » Caucasian children would have a 2.8 times greater chance of presenting crowding in the mandibular arch compared with Japanese-Brazilians.

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The conservative treatment of Class I malocclusion with maxillary transverse deficiency and anterior teeth crowding

Lincoln I. Nojima*

Abstract

This report describes the treatment of a 15-year-old female patient with Angle Class I malocclusion, severe maxillary anterior crowding, maxillary midline shift to the left, and maxillary atresia associated with posterior crossbite. The treatment consisted of palatal expansion using a modified Haas expander and placement of a standard Edgewise fixed appliance. Interproximal reduction was performed on mandibular incisors and canines to align anterior teeth, as well as to reduce Bolton discrepancy due to wide mandibular teeth. This case was submitted to the Committee of the Brazilian Board of Orthodontics and Facial Orthopedics (BBO) in the Free Case category as part of the requisites to obtain the BBO Diploma.

Keywords: Angle Class I malocclusion. Atresia. Palatal expansion. Crowding.

HISTORY AND ETIOLOGY

The main complaint of this 15-year-old female patient in good general health was the position of her maxillary left canine. During history taking, her guardians reported that her adenoids had not been removed. The size of her palatine tonsils was normal. The patient showed

nasal breathing pattern, satisfactory oral hygiene and no severe periodontal condition.

DIAGNOSIS

Facial examination did not reveal any evident asymmetries, but the lower third of the face was slightly longer than expected. The facial profile

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FIGURE 1 - Initial facial and intraoral photographs.

was straight, the nasolabial angle was obtuse, and the upper lip was retruded in relation to the Steiner S line (-1 mm). When smiling, maxillary midline shift to the left could be seen, and her smile was not pleasing because of the labioversion of tooth #23 and palatoversion of tooth #22 (Fig 1).

Intraoral examination revealed Angle Class I malocclusion and anterior crossbite of tooth #12, as well as posterior crossbite. Maxillary atresia resulted in anterior edge-to-edge bite and complete absence of space for the correct alignment

of tooth #23. Dentoalveolar discrepancy was -4 mm and, according to Bolton analysis, discrepancy of the anterior mandibular teeth was 2 mm. There was no overbite or overjet (Figs 1 and 2).

Periapical radiographs showed normal bone trabecula and agenesis of teeth #28, #38 and #48; all other permanent teeth were present (Fig 3). Cephalometric analyses showed a good relationship of maxillary and mandibular bones: ANB = 4° (SNA = 83° and SNB = 79°); and vertical growth pattern with GoGn-SN = 39° (Fig 4, Table 1).

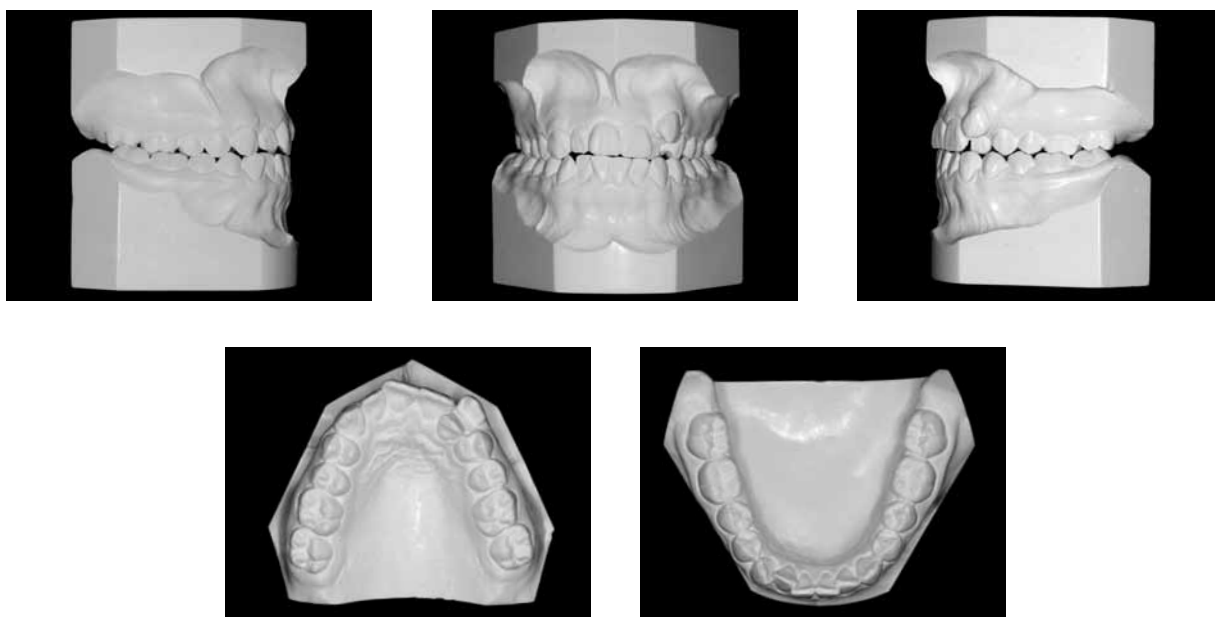


FIGURE 2 - Initial casts.

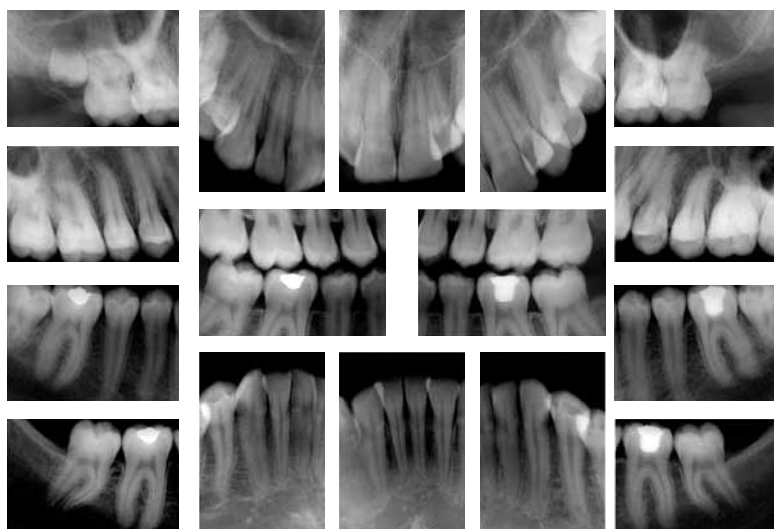


FIGURE 3 - Initial periapical radiographs.

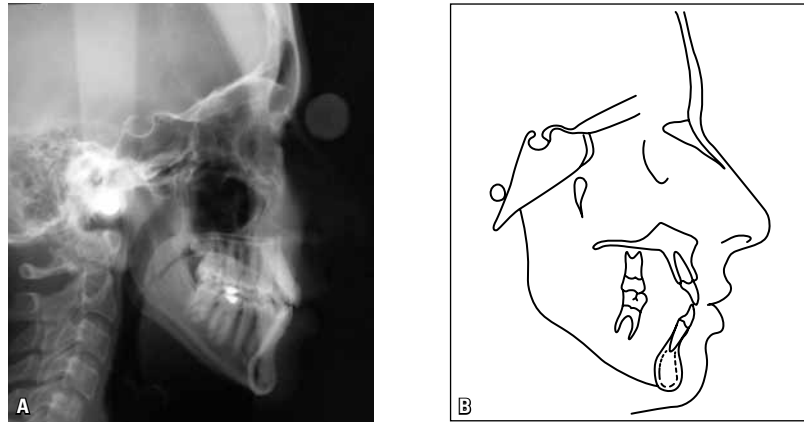


FIGURE 4 - Initial lateral cephalometric radiograph (A) and cephalometric tracing (B).

TREATMENT OBJECTIVES

The purposes of the treatment were to expand the maxillary arch to treat maxillary atresia and crossbite, to gain space to align the maxillary and mandibular anterior teeth, to create adequate overjet and overbite and to correct the maxillary midline. Further objectives were to maintain normal molar occlusion, improve the shape of dental arches, and avoid tooth extractions during orthodontic treatment. For the facial profile, the objective was to keep the balanced position of the upper lip.

TREATMENT PLAN

Palatal expansion was achieved with a modified Haas expander with extension to the lingual surface of tooth #13, followed by the use of standard 0.022 x 0.028-in Edgewise fixed appliance and alignment and leveling using round 0.016-in and 0.018-in stainless steel wires. At this stage, midline was corrected and spaces obtained to correct crossbite of tooth #22 and move tooth #23 to its correct position in the dental arch. Bands were cemented to teeth #36, #37, #46 and #47, and accessories bonded to the other teeth. To align mandibular incisor and canines, 2 mm interproximal reduction was performed and the triangular anatomic shape of

those teeth corrected. Round 0.014-in to 0.020-in wires were used to align and level the mandibular teeth. For finishing, rectangular 0.019 x 0.025-in archwires were used, and first, second and third order bends individually prepared according to the need. A wraparound retainer was used for the maxilla, and a 0.028-in intercanine fixed retainer, for the mandible.

TREATMENT PROGRESS

The patient's main complaint was associated with crowding and crossbite. She received explanations about the need of palatal expansion due to the atresia of the maxillary bone and premaxillary hypoplasia, which resulted in a facial profile with the upper lip positioned behind the esthetic line. The modified Haas expander with extension to tooth #13 was placed. The purpose of the extension was to anchor tooth #13, to which a coaxial 0.028-in wire was bonded on the lingual surface, extending to teeth #12 and #11 (Fig 5). The expander was activated 2/4 of a turn daily, in a total of 8 mm of screw activation. As the interincisal diastema was created, tooth #21 moved mesially towards the open space, and tooth #11 remained anchored to teeth #12 and #13, which avoided its mesial movement towards the diastema and corrected the midline shift.



FIGURE 5 - Occlusal photograph of the modified Haas expander.

A fixed 0.022 x 0.028-in standard Edgewise appliance was then used. Bands were adapted and bonded to teeth #36, #46, #37 and #47, and to the other mandibular teeth except the incisors. In addition, slight interproximal reduction of teeth #42, #41, #32 and #31 was performed. The expander was removed five months after its stabilization, and a 0.045-in buccal archwire was anchored to the 0.051-in buccal tubes, as a retainer for the expansion achieved. For maxillary alignment and leveling, 0.014-in to 0.018-in round archwires were used, and a rectangular 0.016 x 0.022-in blue Elgiloy archwire was used for slight protrusion of maxillary incisors. Immediately after that, the mandibular incisors brackets were bonded, and interproximal reduction of teeth #43 to #33 was performed. Adequate overbite was achieved using a 0.020 x 0.025-in stabilizing archwire with delta loops mesial to teeth #33 and #43, and a 0.019 x 0.025-in maxillary archwire with delta loops mesial to canines, associated with Class II and vertical anterior elastics. Finally, rectangular 0.019 x 0.025-in archwires were manufactured with first, second and third order bends according to the need. Maxillary retention was achieved with a removable wraparound appliance, and mandibular retention, with a bonded 0.028-in intercanine fixed retainer.

TREATMENT RESULTS

The analysis of patient records after active orthodontic treatment revealed that the main treatment objectives had been achieved.¹ Facial profile was improved because of the more anterior position of the upper lip.² Face proportions remained adequate, smile was more harmonious, and the buccal corridor was narrower (Fig 6).

The maxilla gained greater transverse dimensions and a more adequate anatomic width (Table 2). This increase in the upper transverse dimensions affected the intermolar width in the mandibular arch, which resulted in a more vertical position of molars. However, the mandibular plane was increased.³ The space gained in palatal expansion, associated with anchorage of the expander to teeth #11, #12 and #13, resulted in adequate correction of maxillary midline shift and alignment of teeth #22 and #23 (Fig 6).

To align the dental arches, resilient stainless steel archwires were used to define the direction of the forces applied and to move teeth to the desired positions, as well as to obtain a better periodontal response from support tissues. The protrusive movement of maxillary incisors was achieved by the use of mild forces applied by rectangular 0.016 x 0.022-in blue Elgiloy archwires.^{5,6}

To align mandibular teeth, a 2 mm space was created by interproximal reduction of anterior teeth. This procedure promoted the stability of the final position as it increased the contact between these teeth, which had originally an excessively triangular shape (Figs 6 and 7).⁷

Normal molar occlusion was achieved, as well as a good relationship of maxillary and mandibular teeth in static occlusion. The mandibular movements presented normal excursion, with right and left lateral group function, and protrusion with posterior guidance.⁸

Maxillary retention was prescribed for 12 months with a removable appliance to be used 24 hours a day and 12 more months of night use only. Mandibular retention was performed with a 0.028-in stainless steel intercanine fixed retainer.

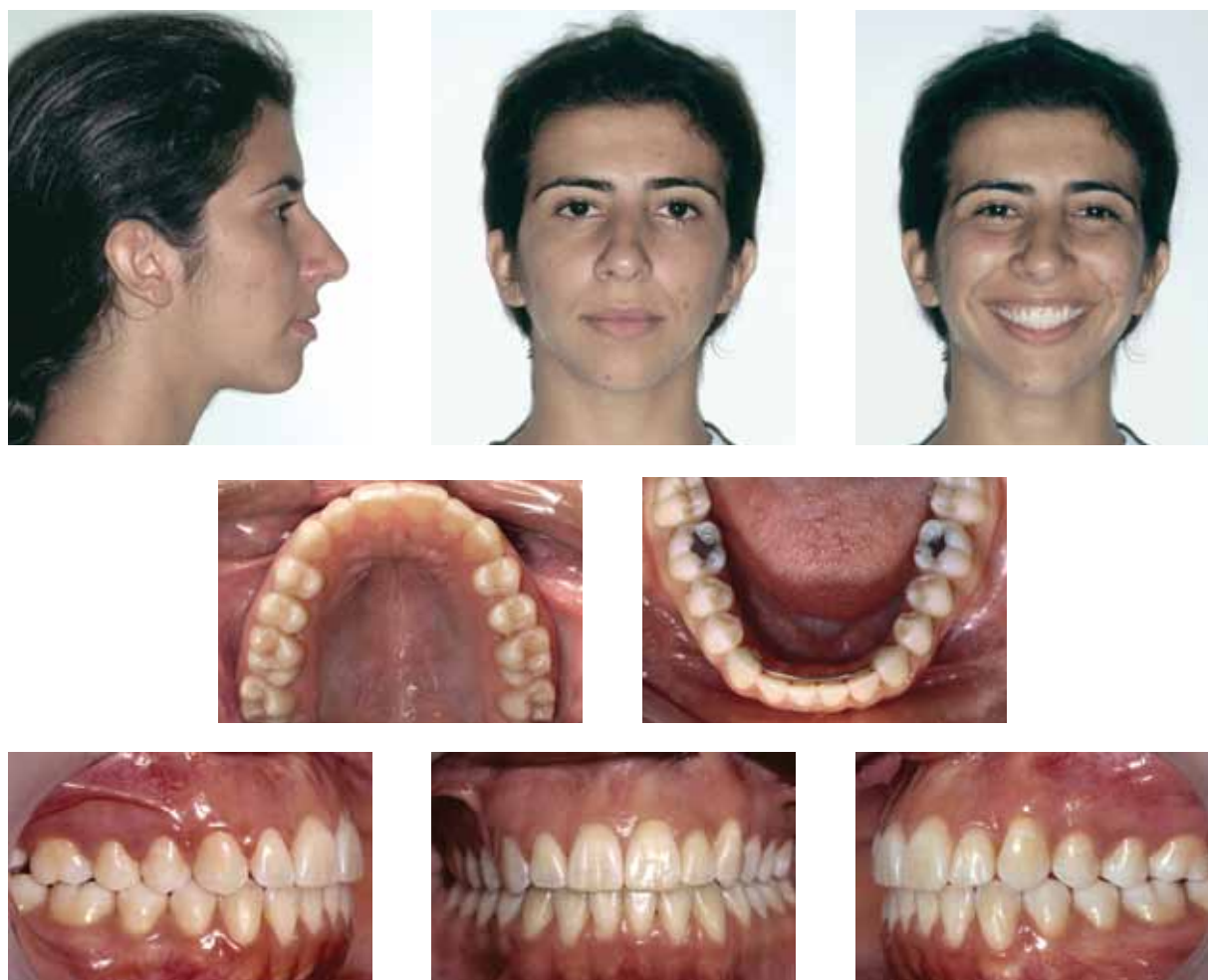


FIGURE 6 - Final facial and intraoral photographs.

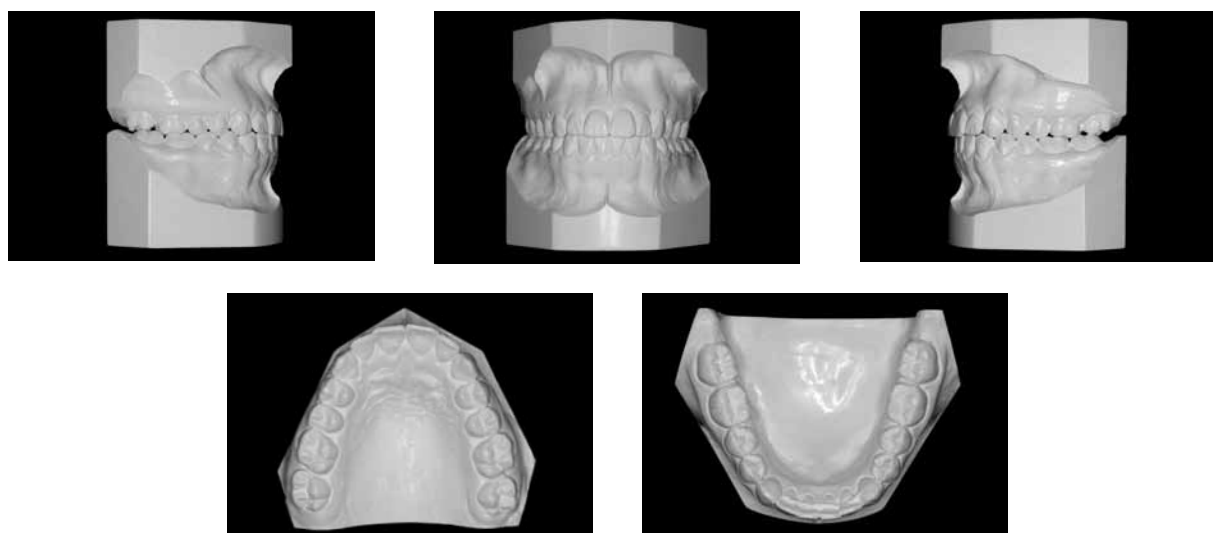


FIGURE 7 - Final casts.



FIGURE 8 - Final periapical radiographs.

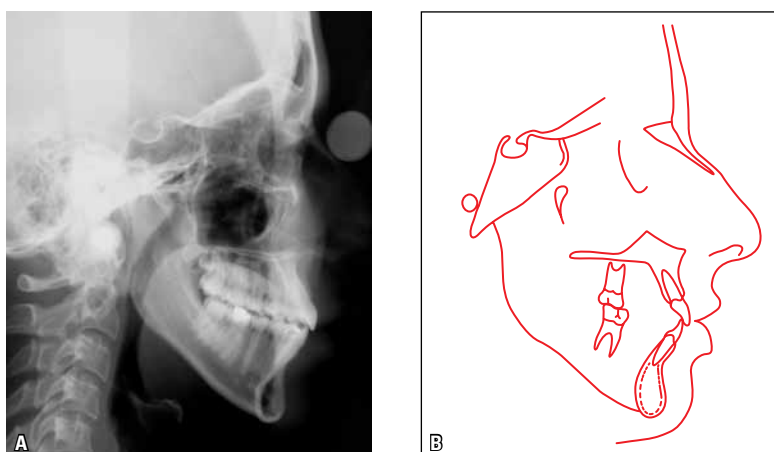


FIGURE 9 - Final cephalometric profile radiograph (A) and cephalometric tracing (B).

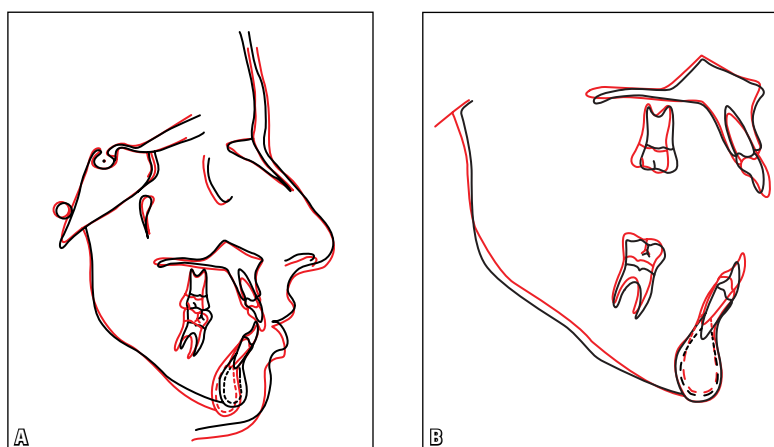


FIGURE 10 - Total (A) and partial (B) superimpositions of initial (black) and final (red) cephalometric tracings.

TABLE 1 - Summary of cephalometric measurements.

	MEASUREMENTS	Normal	A	B	A/B DIFFERENCE
Skeletal Pattern	SNA (Steiner)	82°	83°	83°	0
	SNB (Steiner)	80°	79°	78.5°	0.5
	ANB (Steiner)	2°	4°	4.5°	0.5
	Convexity angle (Downs)	0°	6°	9°	3
	Y axis Angle (Downs)	59°	60°	62°	2
	Facial angle (Downs)	87°	89°	89°	0
	SN-GoGn (Steiner)	32°	39°	43°	4
	FMA (Tweed)	25°	31°	35°	4
Dental Pattern	IMPA (Tweed)	90°	85°	88°	3
	$\underline{1}$ – NA (degrees) (Steiner)	22°	19°	21°	2
	$\underline{1}$ – NA (mm) (Steiner)	4 mm	3 mm	4 mm	1
	$\bar{1}$ – NB (degrees) (Steiner)	25°	24°	31°	7
	$\bar{1}$ – NB (mm) (Steiner)	4 mm	6 mm	8 mm	2
	$\frac{1}{1}$ – Interincisal angle (Downs)	130°	133°	123°	10
	$\bar{1}$ – APo (mm) (Ricketts)	1 mm	3 mm	4 mm	1
Profile	Upper lip – S line (Steiner)	0 mm	-1 mm	-1 mm	0
	Lower lip – S line (Steiner)	0 mm	1 mm	1 mm	0

TABLE 2 - Cast models linear measurements.

CAST TRANSVERSE MEASURES	A	B
Mandibular intercanine width (mm)	24.5	24.5
Mandibular intermolar width (mm)	42.5	44.0
Maxillary intermolar width (mm)	46.5	50

FINAL CONSIDERATIONS

Facial esthetics became harmonious with slight protrusion of upper lips. The treatment of the maxillary arch was more complex due to the skeletal problem of maxillary atresia associated with the vertical growth pattern, in addition to other problems, such as the maxil-

lary midline shift to the left. To align and level teeth #22 and #23, palatal expansion was associated with the forward movement of incisors and the use of Class II elastics in the left side. To correct the -4 mm mandibular crowding, 2 mm interproximal wears were performed in teeth #33 and #43, and mandibular incisors were slightly moved forward (Figs 8, 9 and

10; Table 1). Total superimposition (Fig 10A) showed clockwise rotation of the mandible, and partial superimpositions (Fig 10B) showed distal movement of tooth #26 and protrusive movement of maxillary and mandibular incisors. The extraction of the maxillary third molar (#18) was recommended because of the expansion of its follicle.

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Enamel drilling for canine traction: Advantages, disadvantages, description of surgical technique and biomechanics

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Abstract

Introduction: The management of unerupted teeth has always been considered as a challenging procedure in orthodontic practice. Within this perspective, the search for effectiveness in the procedures adopted for the management of unerupted teeth is essential, which explains the purpose of the present paper. When enamel drilling is performed, a natural structure is transfixed, which may be restored with composite material and may dispense from risky procedures such as bonding attachment technique and lasso wire technique. **Objective:** The present paper aims to present protocols for enamel drilling for canine traction (EDCT), specifically for maxillary canines, the most frequent teeth showing tooth position anomalies. In this paper, clinical cases with different degrees of complexities were illustrated, and, based upon the literature review and the 30 years of expertise with high rate of clinical success, advantages and disadvantages are discussed comparing EDCT and accessory bonding for canine traction (ABCT).

Keywords: Canine impaction. Tooth traction. Segmented arch mechanics.

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INTRODUCTION

The most frequent absence of teeth in the dental arch involves permanent canines, if third molars are not taken into account.^{21,28,36} In random samples, the frequency of unerupted canines ranges from 1.5 to 2% in the maxilla, and 0.3% in the mandible^{10,20,22,23,26,30,35} Conversely, frequency is high (23.5%) in samples previously selected for orthodontic treatment.^{3,24,37} In female patients the unerupted canines (1.17%) are twice as frequent as in males (0.51%)² and occur palatally two to three times more often than buccally.^{1,33}

Although hereditary³³ factors seem to play a role in the pathogenesis of unerupted teeth, especially in palatal occurrences, the exact causes are still unknown.³⁴ Among the factors most often associated with unerupted teeth are discrepancies between tooth size and arch length, abnormal position of the tooth germ or tooth, prolonged retention or early loss of deciduous teeth, the occurrence of cystic or neoplastic formation and iatrogenic causes.^{2,4} Although unfounded, other etiologies are sometimes mentioned, such as systemic causes.

The diagnosis and treatment of unerupted teeth requires competent general practitioners, pediatric dentists, oral and maxillofacial surgeons, periodontists and orthodontists, as well as patient compliance.^{31,36} Prognosis for the use of tooth traction should be considered with serious reservation, or at least rather limited at first because the chance of failure can never be ruled out as it depends on many variables.³⁸ Parents or legal guardians should be made keenly aware of the odds to avert false expectations.

Conventional radiographic techniques have always presented limitations in locating unerupted maxillary canines, especially panoramic X-rays, which require additional radiographs such as periapical X-rays by the Clark technique¹⁰ or occlusal maxillary radiographs. These techniques were limited and could only spot unerupted canines buccally or palatally, but the relationship

between canines and adjacent teeth was not addressed and the potential loss of the root structure of lateral incisors (which are most commonly affected teeth in these situations) was totally unknown. Orthodontic planning was thereby curtailed since it was only possible to assess these variables and the integrity of the lateral incisor root during the surgical procedure performed in order to access the unerupted canine. Common sense, caution and periodic controls were a necessary support to ensure that procedures based on this limited diagnostic came to fruition.

Cone beam computed tomography (CBCT) made the diagnosis of anomalies in the position of maxillary canine, also called dysgenesis, much more effective. CBCT's various slice planes and the resulting 3D reconstructions, viewable from virtually every angle, allows today's professionals to plan orthodontic traction of maxillary canines with greater accuracy and refinement. This allows surgeons to deal with canines, their dental follicle, cervical region and adjacent teeth with the aid of detailed planning, which ultimately reduce the risks of unintended outcomes. In other words, technological advances in imaging have increased the chances of orthodontic traction being accomplished more safely and accurately. It also eliminates the possibility of preexisting processes such as external cervical resorption, alveolar ankylosis and replacement resorption in the teeth to be submitted to traction.¹⁷ When the imaging diagnosis reproduces more faithfully the actual position, the prognosis tends to be more precise and the treatment plan can be tailored to the individual.

With the purpose of individualizing the mechanics in terms of the direction of orthodontic traction forces, it was, and still is, adequate that orthodontists be invited to watch the surgery in order to view the exact position of the unerupted canine. As a result, traction would be planned and all such details noted in the patient's records. When the orthodontist was not

present during surgery, it was requested that information was described in an official referral to enable safer traction. Maintaining this hypothesis, the surgeon must have enough orthodontic knowledge to guide the orthodontist on how best to perform the movement.

Early identification of non-eruption of the canine may reduce the need for complex and expensive orthodontic treatment. It is important that general practitioners and pediatric dentists be vigilant when monitoring eruption in children in the mixed dentition stage, not just by taking care of oral health, but also by identifying potential disruptions in this process. Ectopic eruption and impaction of maxillary permanent canines are frequent issues in orthodontic practice. In addition to being regarded as real challenges for the orthodontist, these two oral conditions can significantly lengthen total treatment time¹¹ as well as increase treatment complexity.⁸

In planning treatment of an unerupted canine, one is advised to assess the thickness of the dental follicle, bearing it in mind when creating space to accommodate this tooth in the dental arch, aiming at either normal canine eruption or its orthodontic traction. The space required for the physiological eruption of an unerupted canine is, in theory, 1.5 times the mesiodistal size of the canine crown, a necessary condition for eruption to occur without orthodontic assistance.^{12,15}

In patients with unerupted canines, the corresponding deciduous teeth are usually found in the arch and their mesiodistal dimension is much smaller than that of the permanent canine. Creating space in the analogous arch for the mesiodistal dimension of the unerupted canine is a daunting task and often impossible to achieve, especially if the goal is to increase space by 50%.¹² It is usually impractical, from a mechanical point of view, to wait for a physiological eruption, and this is precisely why

traction is indicated. Monitoring the patient and the risky relations of this tooth with the neighboring teeth will determine the appropriate moment for this approach.

When the patient's face and the transverse dimensions of the upper arch can support it, orthopedic maxillary expansion seems unquestionable with this protocol – a *sine qua non* condition for a real increase in bone mass by adding bone to the midpalatal suture – creating space and enabling a better eruption pathway. The goal is a real bone gain by placing bone in the region of the midpalatal suture and increasing the perimeter of the arch. This creates favorable conditions for the canine to find eruption space and redirect its pathway, often avoiding surgical approaches and orthodontic traction. This is only possible within a follow-up perspective with growth monitoring and assisted eruption, where these problems are diagnosed at an early stage, enabling an interceptive procedure and subsequent follow-up to assess progress.

According to the literature, several therapeutic treatment options are available for patients affected by this anomaly, namely: Absence of immediate treatment and long-term monitoring, self-transplantation of the canines, extraction of unerupted canines and closing of spaces with restorative treatment, extraction of unerupted canines and closing of spaces with orthodontic treatment, and finally, surgical exposure of unerupted canines and use of orthodontic forces to bring the tooth into occlusion.^{2,4,31,32,35}

When canine traction is indicated, the surgical approach is performed and the tooth prepared for this procedure by tying the tooth, bonding a fixed orthodontic appliance or drilling the crown enamel. This is one of the procedures that can be performed in orthodontic treatment to position teeth in the dental arch without compromising normal esthetics and function.¹⁹

There is consensus indicating that the canine should never be tied with wire because of the inherent difficulty posed by this procedure and because it causes cervical resorption as the steel ligature is placed along the cemento-enamel junction (CEJ). Historically, the first protocols used in the traction of unerupted maxillary canines consisted in binding the neck of the tooth with steel wire. The force and displacement of the orthodontic wire on the neck of the tooth would expose the dentin gaps in the CEJ, adding to the constant inflammation that resulted from the continuous trauma.¹⁷

Accessory Bonding for Canine Traction (ABCT) and Enamel Drilling for Canine Traction (EDCT) are the most common procedures. ABCT is perhaps the technique of choice of most dentists as it prevents erosion of tooth structure. Contrary to the choice of most orthodontic colleagues, the authors of this article never performed the ABCT procedure for reasons that will be presented in this paper, and have always applied the EDCT procedure for this purpose. This technique was successfully applied over thirty years of orthodontic practice and now boasts a caseload with 100% successful cases, which justifies its disclosure to the scientific community. In addition to this outstanding accomplishment, it should be emphasized that not a single canine ever required further treatment, which was the main reason for always choosing this option. Over time, a protocol for this procedure was formulated and is presented below. The EDCT technique can be adopted in all cases with no restriction because drilling can be performed in different areas of the crown of the unerupted canine, according to how one needs to move this tooth.

In light of the above, the aim of this paper is to create protocols for EDCT technique, specifically for maxillary canines since these teeth are more often affected by position anomalies, also called dysgeneses. By describing the advantages

and disadvantages of EDCT compared with the ABCT technique, illustrated through case studies of different levels of complexity, the primary intention is to create a concise methodology, based on the literature and filtered through clinical experience of over thirty years performing EDCT with a high success rate.

ADVANTAGES AND DISADVANTAGES OF ENAMEL DRILLING FOR CANINE TRACTION (EDCT): COMPARATIVE ANALYSIS

Advantages

Decreased risk of a new surgical procedure

The risk of a new surgical procedure to access the unerupted canine may occur in the ABCT technique due to immediate bond failure of the accessory after delivery of the traction force. This bond failure may be caused by excessive force and/or contamination during the process of bonding the orthodontic accessory. Considering that most patients eligible for traction are children, management may prove more difficult, with increased risk of this occurrence while exposing them to a new surgical procedure, a risk that could certainly be avoided. Therefore, the authors' preference for EDCT – despite the biological cost involved (wear of enamel, a structure that is not replaced by the body) – considerably reduces the possibility of reopening for new access to the unerupted canine, since when this tooth is tied the risk is virtually nonexistent.

Less tissue manipulation

The dental follicle (DF) is the essential and fundamental structure in tooth eruption. The epithelial structures of the dental follicle – such as the reduced epithelium of the enamel organ and the islands/cords of epithelial remnants of the dental lamina – constantly release epidermal growth factor (EGF) in the connective tissue (CT). This mediator, along with other

EGF-activated mediators, induces pericoronal bone resorption, an essential phenomenon in the occurrence of tooth eruption.

The cemento-enamel junction lies between enamel and cementum. It is therefore reasonable to assert that the DF in the cervical region overlies the line formed by the neighboring relationship between enamel and cementum. The CEJ has gaps along the cervical circumference of all human teeth in which the tubules are open and exposed to inorganic and organic components, but especially proteins. This cervical region is a sensitive tooth structure due to the fragile junction between enamel and cementum.^{16,17}

During surgical removal of the DF in the cervical region the dentin gaps present in all human teeth, including deciduous teeth, are inevitably exposed to connective tissue after the flap is folded back over the tooth. The exposure of these dentin proteins, defined as sequestered antigens, can induce, over weeks or months, an immunological process of elimination that is clinically known as External Cervical Resorption (ECR). This process may occur during orthodontic traction or after the tooth has reached the occlusal plane.^{16,17} In many such cases a belated detection tends to be the rule. ECR is defined as a slow, painless, insidious process that does not compromise pulp tissues. In more advanced cases, it can lead to gingival inflammation and pulpitis secondary to bacterial contamination. One way to prevent this occurrence is to leave at least 2 mm of soft tissue from the DF attached to the cervical region.^{16,17}

The ABCT technique requires greater exposure of the crown and hence greater need to remove osseous tissue and manipulate the DF, implying a higher risk of trauma to the ECJ. This region should be handled only when absolutely necessary.^{16,17} When this occurs, the chances of external resorption in this region after the traction procedure are increased, which causes loss of structure of the tooth under traction.

This effect can be further compounded by excessive or extensive application of acids and other products used to etch the tooth enamel. Over-application can drain these products into the cervical region, where fixation of the DF to the ECJ occurs, chemically affecting cells and tissues, exposing and even increasing dentinal gaps and releasing the sequestered antigens into the adjacent tissue after the surgical wound has healed.^{16,17}

The surgical procedure must be well planned and carried out with precision, without exaggerated forces and repetitive handling of the instruments used in the procedure.¹⁹ Surgical instruments should not be anchored or fixed to the cervical region of the upper canines because chisels and tips of surgical instruments such as forceps can mechanically damage the follicle and periodontal tissues in the cervical region and expose or increase the exposure of the dentin at ECJ, a starting point for ECR.^{16,17}

When drilling is the procedure performed to access the unerupted canine, only a small portion of the tooth crown requires exposure, and only enough to allow the procedure to be performed. This portion of the crown may be the tip of the cusp or any of the proximal surfaces, depending on the anatomical features of the canine, which displays an enamel bridge along the entire crown with sufficient strength to withstand anchorage and traction.

After performing the surgical procedure a wound is formed from damaged epithelium and exposed connective tissue over the enamel. The reduced epithelium of the enamel organ tends to proliferate rapidly, covering once again the enamel and the ligature wire placed in the perforation over a period of hours or days. The underlying connective tissue starts forming again from the granulation tissue that grows temporarily in the area. Thus, the enamel is not exposed to the connective tissue until the tooth reaches the oral environment.^{16,17}

Shorter surgery time

The EDCT technique eliminates the need for conventional steps of regular bonding, which involves etching, moisture control, adhesive application and bonding of orthodontic accessory. Performing all these steps in an environment with total moisture control requires more time in the trans-surgical phase, considering the difficulty of this procedure, which is carried out through surgical exposure of the canine in an open field. In addition, the surgical procedure must be performed by a competent oral and maxillofacial surgeon, although these professionals, more often than not, have little experience in bonding orthodontic accessories. The EDCT technique eliminates all the steps listed above, which results in shorter surgical time, less bleeding and therefore less postoperative edema.

Application of force in the long axis of the tooth with a better established magnitude

The EDCT technique allows the application of force directly to the long axis of the tooth under traction, resulting in increased control over traction direction. When an accessory is bonded to the buccal or lingual surface of an unerupted canine and traction force is applied, the direction of the resultant force should be observed in order to avoid undesired movement.

Moreover, the presence of a bulky body such as a bracket or button on the surface of the canine in an area subjected to a repair process after access surgery probably restricts canine movement making it difficult to determine the amount of force to be applied. Admittedly, the ideal force must be small in magnitude, ranging from a minimum amount of around 35 to 60 grams, when traction copies an eruption movement, to greater forces, required when the canine needs to undergo translatory forces in order to avert obstacles in its eruption pathway. In either case, determining an adequate force

is rendered more difficult if restrictive factors, such as the ones mentioned above, establish undefined magnitude decreases in the force available to perform the movement of traction.

Disadvantages

Risk of enamel fracture

The EDCT technique requires care to prevent the enamel from fracturing when twisting the ligature wire. Stronger ligatures are often used for this purpose, i.e., so that the risk of fracture and consequent need for reopening are minimized. Twisting the ligature without considering basic precautions, as inserting the explorer probe tip between the ligature and the canine, can cause enamel fracture and require new drilling, further increasing the biological cost of the procedure.

Potential pulp damage

Canine drilling should be performed perpendicular to the long axis of the tooth with a small diameter ($\frac{1}{4}$ ") high speed spherical carbide bur and copious irrigation. This is important to prevent the bur from reaching the pulp chamber, thereby causing irreversible pulpitis or even requiring endodontic treatment. The competence and experience of a professional surgeon is of paramount importance to avoid such damage.

Some patients report sensitivity after drilling, and during traction a direct friction between ligature and tooth structure may cause minor discomfort, which should be considered normal as it is quite tolerable. Normally, when the canine emerges in the oral cavity the patient is referred to a specialist in Esthetic Dentistry and the perforation is restored, minimizing sensitivity. Be it as it may, throughout the many years of experience that underpin the protocol presented in this paper, complaints have never been greater than reported and biological damage has never been observed.

Esthetics

When the EDCT technique is performed, the hole drilled during the procedure should be filled by means of esthetic restoration following the emergence of the unerupted canine in the oral cavity. Given the ongoing advances in dental restorative materials and assuming that this procedure is performed by a competent professional – by drilling a big enough hole as to allow the passage of a folded ligature wire – it is unreasonable to suspect that drilling might impair esthetics. As stated earlier, a spherical ¼" diameter carbide bur should suffice.

Greater professional experience

The EDCT procedure requires an experienced, insightful surgeon to determine the actual position of the unerupted canine since this drilling, as previously stated, should be performed perpendicular to the long axis of the tooth, despite the reduced need for removal of osseous tissue and manipulation of the DF. The cases that require greater attention are those with severe impaction because the procedure – which involves a flap in an open field, as well as the presence of bleeding – is usually performed in children or adolescents, with little if any collaboration, under local anesthesia, protocol usually adopted by the authors' surgical team.

ADVANTAGES AND DISADVANTAGES OF ACCESSORY BONDING FOR CANINE TRACTION (ABCT): COMPARATIVE ANALYSIS

Advantages

Lower biological cost

Since the ABCT procedure does not require drilling of the unerupted canine crown, it entails a lower biological cost compared to the EDCT technique, i.e., canine structure is fully preserved. It is worth mentioning that this

biological cost is decreased as long as care is exercised in washing the canine crown after etching so as not to allow the acid to remain in the DF when the ABCT technique is performed.

Lower risk of pulp damage

When the ABCT procedure is performed, drilling of the unerupted canine crown is not necessary and therefore the risks related to pulp damage are minimized or virtually eliminated. The risk of pulp damage is related to a poorly executed EDCT technique, i.e., when drilling is not performed perpendicular to the long axis of the unerupted canine.

Disadvantages

Increased manipulation of the dental follicle (DF)

It should be noted that the ABCT technique requires exposure of the unerupted canine crown so as to create a surface large enough to bond the attachment used for traction. Therefore, the need to remove osseous tissue is greater as is the manipulation of the DF during the surgical procedure. Whenever these tissues are over-manipulated the biological costs are higher, as well as the risks of ECR occurring after traction of the unerupted canine.

Longer surgery time

The ABCT technique requires more surgical time because besides the usual procedures there is the need to perform the steps of a conventional bonding procedure, which involves etching, moisture control, primer application and bonding of orthodontic accessory, while at the same time striving to control bleeding so that the risk of a bond failure is minimized during the traction movement. All these steps increase trans-surgical time, causing discomfort to the patient due to a longer procedure and more bleeding during surgery and, consequently, more postoperative edema.

Force application

Forces induced to perform traction of unerupted canines should be directed, whenever possible, using the long axis of the tooth as reference. Typically, the bonding of a bracket or lingual button to the mesial region of the clinical crown of an unerupted canine does not allow the traction force to make the tooth copy the eruption movement. Since the bonding of this accessory, which will receive the wire and the traction forces are routinely performed in less than ideal positions, resulting from unfavorable technical conditions and the need to restrict tissue manipulation, canine

displacement can follow undesired pathways. This may present risks for the adjacent teeth and require more extensive movements for the proper positioning of the canine after its emergence in the oral cavity (Fig 1).

Even in this context of inadequate movement of the canine, an additional difficulty lies in defining the level of force, which should be at the same time light and suitable for the traction movement. In other words, copying the eruption movement or predicting the type of displacement that the canine will perform during eruption caused by orthodontic traction, seems to be very important and made difficult when the ABCT technique is adopted.

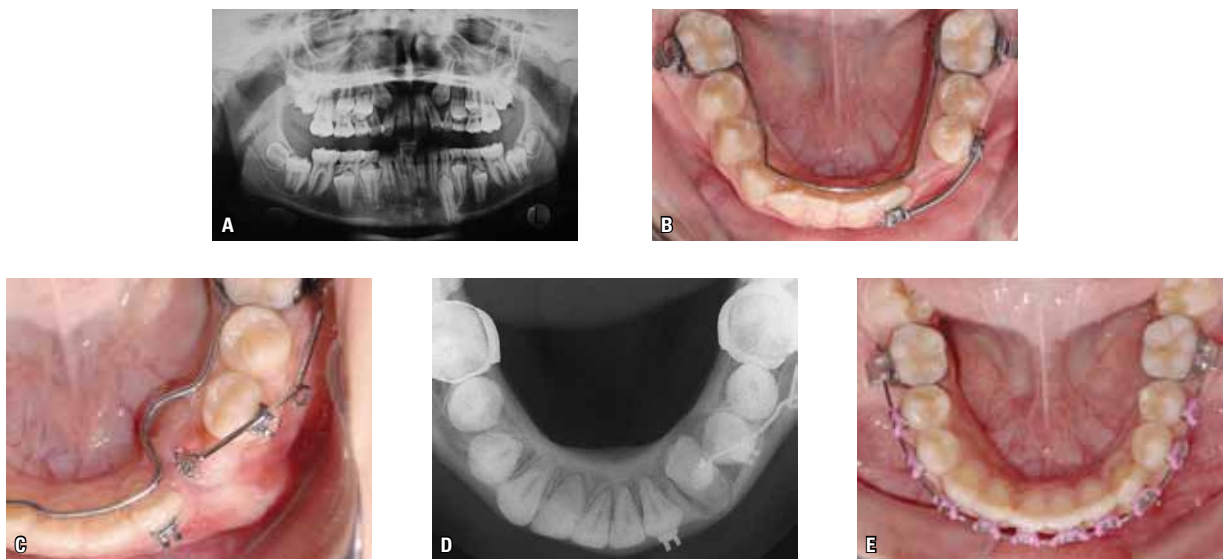


FIGURE 1 - A) Initial panoramic X-ray of a patient with tooth #33 unerupted (contributed by Prof. Dr. Daniela Garib). **B)** Lower occlusal image taken after the beginning of orthodontic treatment with anchorage on a lingual arch welded to bands placed on teeth #36 and #46 – with double rectangular tubes – in addition to a segmented fixed appliance with brackets on teeth #32 and #34, partial lower leveling and lower closed coil spring for space maintenance. Surgical access was achieved through the ABCT technique and the orthodontic appliance was bonded to the cervical third of the buccal surface of the canine crown. A cantilever resting on the rectangular double tube of tooth #36 was fabricated to pull tooth #33. Note the bulging in the region of the bottom of the buccal groove (**C**), a likely consequence of the unfavorable movement of tooth #33, confirmed by occlusal radiographs of the mandible (**D**). The canine was once again accessed and the orthodontic accessory rebonded on the incisal third of the crown for a more controlled movement, which ensured orthodontic treatment success (**E**). Probably, access to tooth #33 through the EDCT technique would prevent such mechanical hindrances because the force is inserted directly into the long axis of the tooth, allowing for improved control and direction of traction.

CLINICAL CASES THAT ILLUSTRATE THE ENAMEL DRILLING FOR CANINE TRACTION (EDCT) TECHNIQUE

In this topic, the EDCT surgical technique will be demonstrated through case studies that disclose different levels of complexity, which will be discussed in the captions of each figure.

EDCT	ABCT
Decreased risk of new surgical procedure	Risk of new surgical procedure due to accessory bond failure
Less tissue manipulation	Greater manipulation of tissues to expose tooth surface
Shorter surgery time	Longer surgery time
Direction of force in the long axis of the tooth	Direction of force dependent on accessory positioning
Risk of enamel fracture	No risk of enamel fracture
May cause pulp damage	Minimal pulp damage
Future need for esthetic restoration	Less potential need for esthetic restoration
Demands a more experienced surgeon	No need for experience in drilling
No acid action on tooth	Acid action on tissues at CEJ and DF

TABLE 1 - Comparison between advantages and disadvantages in using Enamel Drilling for Canine Traction (EDCT) versus Accessory Bonding for Canine Traction (ABCT).

CLINICAL CASE 1



FIGURE 2 - Female patient, nine years and six months old, Caucasian, Pattern I^s brachyfacial was referred by a pediatric dentist for orthodontic evaluation due to routine radiographs indicating poor positioning of the maxillary permanent canines. In the second transitional period of mixed dentition, the intraoral examination (A-E) revealed a Class I occlusal relationship bilaterally with adequate overbite and overjet. In occlusion, the upper midline was found slightly deviated to the left relative to the lower midline. In the upper arch, teeth #12 and #22 had distal angulation and labial inclination of the crown, and lower arch exhibited mild crowding in the lower incisor region. Both deciduous canines were present, with no mobility and the permanent successors had no palpable area, nor root apex closure. With regular monitoring and good dental hygiene, the patient had not undergone previous orthodontic treatment. Patient history revealed no oral habits, medical problems or eruption disorders in the family.



FIGURE 3 - The initial panoramic radiograph confirmed the presence of all permanent teeth and evidenced the reason for the consultation: Malposition of teeth #13 and #23 associated with divergence of the crowns of teeth #12 and #22, characteristic of the inter-transitional period of mixed dentition, despite the fact that the patient was in the beginning of the second transitional period. Radiographically, the upper permanent canines were mesially angulated, with tooth #23 in a critical position, i.e., near the roots of the maxillary permanent lateral incisors, with the apices of the permanent canines not yet closed.



FIGURE 4 - A technique of horizontal displacement of the tube (Clark technique)¹⁰ using periapical radiographs confirmed that the upper left canine was impacted in a palatal position. This was the reason for the consultation and the need for treatment. The time was entirely appropriate for treatment as it enabled a strategy aimed at improving the prognosis, which is always limited. This possibility was provided by a competent pediatric dentist who perceived the problem and made the referral. The treatment for this patient was designed to intercept the pathway of the ectopic tooth #23, which was in a more critical position than tooth #13.



FIGURE 5 - Access planning and preparation for traction of tooth #23, maxillary expansion and initial traction of the canine with a cantilever supported on the expander. All aspects of the case were discussed in detail during a follow-up consultation. The options and potential complications of mechanical traction were discussed with the patient and their legal guardian(s), who accepted the suggested treatment plan. They received a written form of consent informing them about the treatment options available for the impacted tooth and the potential complications associated with the mechanics. The surgical technique consisted in exposing the crown of tooth #23 enough to drill a small hole with a small diameter ($\frac{1}{4}$ ") spherical carbide bur for the passage of a folded ligature wire, which would be subsequently twisted. The patient returned a week later when the stitches were removed and the next step involved the banding of teeth #55 and #65 and taking an impression to work on the upper arch with a view to fabricating the Haas expander, modified according to the changes suggested by Capelozza Filho et al.⁷ During this period, the ligature wire was left on the palatal region of tooth #63.



FIGURE 6 - The expansion appliance was cemented with internal and external connecting bars bonded with resin to the buccal and palatal canines and first primary molars in order to enhance anchorage, in addition to extension bars for teeth #16 and #26 (A). Before starting the active phase of expansion the ligature wire tying tooth #23 was attached to the structure of the Haas expander (B and C).



FIGURE 7 - The maxillary orthopedic expansion seems unquestionable in this protocol, in the sense that it is undoubtedly a condition for a real increase in bone mass by adding bone to the midpalatal suture, thereby creating space and enabling a better eruption pathway for tooth #13 as well. The extremely favorable timing with which this procedure was performed improved the prognosis and facilitated treatment. After maxillary expansion and expander screw fixation (A), a segment of TMA wire (0.019 x 0.025-in) was adapted to the Haas appliance through a hole in the acrylic made with a steel round bur and fixed with acrylic resin. After curing the resin, tooth #23 began to be pulled in the palatal and occlusal direction, delivering an amount of force equivalent to 60 grams (B and C). The initial palatal movement was meant to prevent contact between the crown of tooth #23 and the root of tooth #22, thus reducing the risk of root resorption. This is the usual practice to protect the roots of adjacent teeth during induced canine eruption movement.

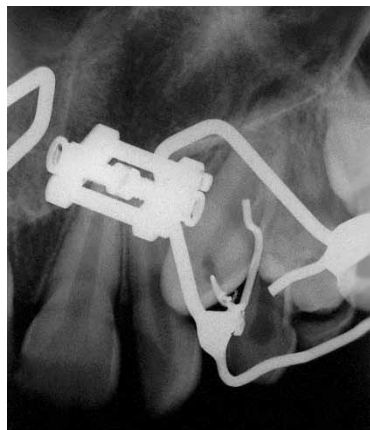


FIGURE 8 - After five months of traction, a periapical radiograph was taken of the region in which it appeared that the traction movement had allowed for the correction of the eruption pathway of tooth #23. In this phase, the partial removal of the Haas expander was indicated.



FIGURE 9 - The ligature which had been transfixed through tooth #23 was then tied to the remainder of the expander – which was partially removed – at the external connecting segment on the left side. In this phase, tooth #23 started moving buccally with the ligature supported on the distal surface of tooth #63.



FIGURE 10 - Intraoral photographs (A-E) seven months after initiating mechanical traction of tooth #23 (one month after the force was directed buccally), showing the tip of the canine cusp already in the oral cavity, palatally (D). In this phase, the remaining expander segment was removed and teeth #63 and #64 extracted. Interception of the ectopic eruption pathway of tooth #23 was resolved and, as of this phase, time was allowed to elapse until all teeth had been replaced before starting corrective orthodontic treatment. Prognosis is good for corrective treatment, unlike what was determined at the beginning of treatment, thanks in part to the ectopic eruption pathway of tooth #23. A panoramic radiograph (F) was requested for evaluation at the end of the second transitional period of mixed dentition, pending only the exfoliation of tooth #55, whose extraction was requested. In this phase, at the age of ten years and six months, the patient was instructed to resume corrective orthodontic treatment after complete eruption of teeth #15 and #25.



FIGURE 11 - New orthodontic records (A-E), with the patient aged ten years and nine months, confirmed that the interceptive treatment for correction of the eruption pathway of tooth #13 and, especially, tooth #23 evolved satisfactorily. Periapical radiographs (F, G, H) show an adequate development of spontaneous eruption of tooth #13 and traction of tooth #23. The occlusion attests to the simplicity of the treatment to be performed to position tooth #23.

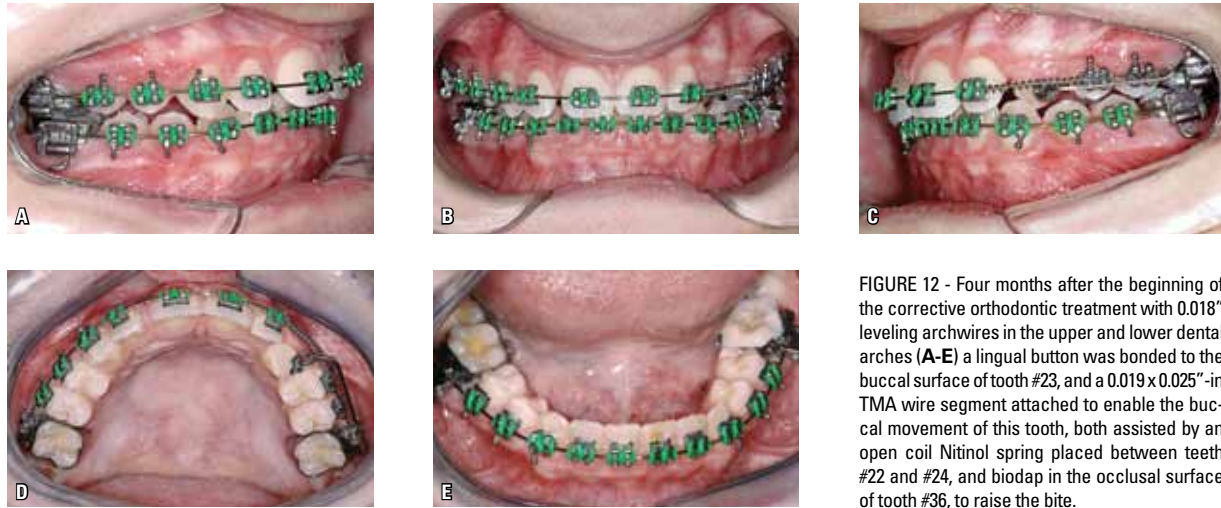


FIGURE 12 - Four months after the beginning of the corrective orthodontic treatment with 0.018" leveling archwires in the upper and lower dental arches (A-E) a lingual button was bonded to the buccal surface of tooth #23, and a 0.019 x 0.025"-in TMA wire segment attached to enable the buccal movement of this tooth, both assisted by an open coil Nitinol spring placed between teeth #22 and #24, and biodap in the occlusal surface of tooth #36, to raise the bite.

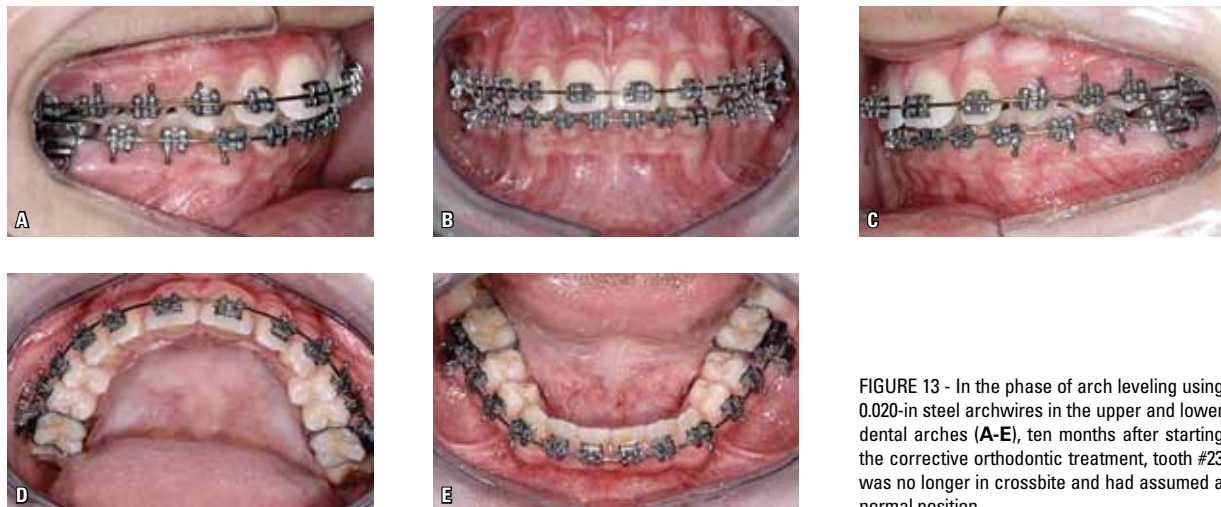


FIGURE 13 - In the phase of arch leveling using 0.020-in steel archwires in the upper and lower dental arches (A-E), ten months after starting the corrective orthodontic treatment, tooth #23 was no longer in crossbite and had assumed a normal position.



FIGURE 14 - A radiographic evaluation, performed in order to finish the case and remove the orthodontic appliance, displayed satisfactory parallelism between the roots, including maxillary canines.



FIGURE 15 - Intraoral control photographs two years after removal of the appliance (A-E) exhibited stability of occlusal relationships achieved by implementing an expansion and protrusion mechanics, and confirmed by long-term follow-up.

CLINICAL CASE 2



FIGURE 16 - A description of the treatment for traction of a retained canine through the buccal side will be illustrated with the case of a Caucasian girl, probably Pattern I,⁵ and mesofacial, who participated in a growth and eruption monitoring program and was subjected to an initial assessment when she was nine years and nine months old. At this early time, a lack of motivation to present for the consultations affected the eruption of the upper lateral incisors. At the end of the first period the mixed dentition exhibited a Class I occlusal relationship. Although there were no crossbites, the upper dental arch morphology suggested atresia, a hypothesis which, if true, would lead to a diagnosis of compensatory adjustment atresia in the lower arch as well.



FIGURE 17 - The panoramic radiograph (A) showed the presence of all teeth and confirmed a change in position of tooth #12 (moderate) and tooth #22 (severe), with an inappropriate intraosseous relationship between its roots and the crowns of the canines, confirmed by means of periapical radiographs (B, C, D). In the protocol adopted by author's team, rapid maxillary expansion has a twofold indication in the context of the circumstances just described: To correct the hypothetical atresia of the upper arch, eliminating the transverse compensation of the lower arch and, importantly, to create a bone area to allow an adjustment in the relationship between lateral incisors and canines.



FIGURE 18 - And so it was done. The modified Haas type expander was cemented and an expansion lip bumper installed, following the protocol recommended for this approach⁶ (A-E).

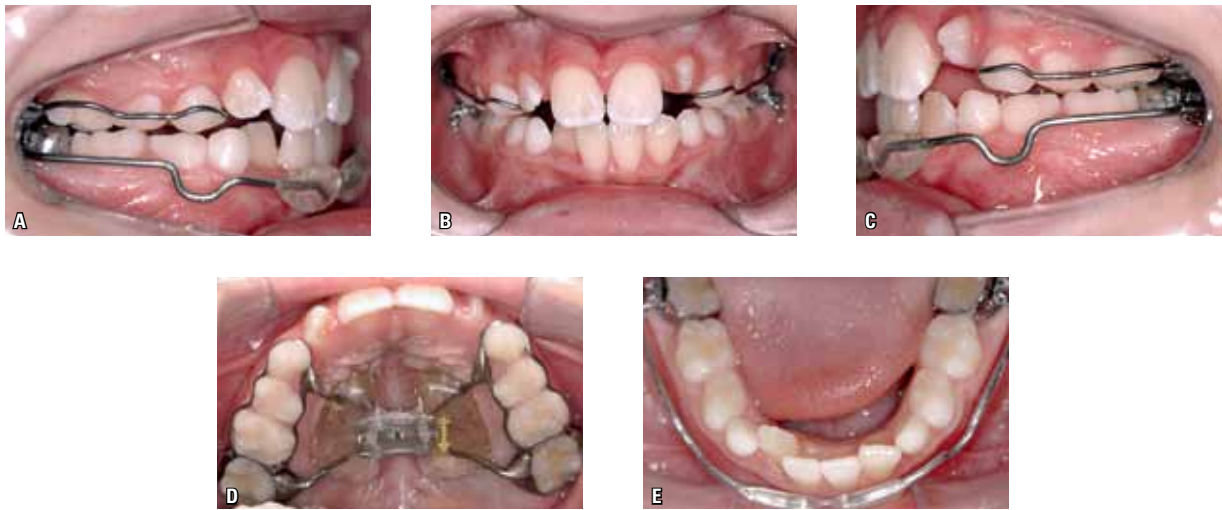


FIGURE 19 - The results achieved in the shape of the dental arches – with the obvious advantage of creating space to accommodate the crowns of lateral incisors – can be observed (A-E), hopefully improving the relationship between the roots of these teeth and the canine crowns.



FIGURE 20 - The expander was removed after four months and the lip bumper maintained for night use. Eight months after this intervention of an essentially interceptive and preventive nature, Clark¹⁰ technique periapical radiographs showed that tooth #13 had improved and tooth #23 was positioned outside the normal eruption pathway, buccally, interfering with the positioning of tooth #22. A clinical decision was made to request the extraction of teeth #53 and #63 and wait for the eruption of tooth #24.



FIGURE 21 - Five months after, with the patient aged ten years and ten months, the eruption of tooth #24 had occurred and it was time to intervene. A new radiographic evaluation was performed using the Clark¹⁰ technique, which confirmed the adequate period for a surgical approach.



FIGURE 22 - At eleven years and one month, following the protocol that provides for the traction of tooth #23 by means of segmented arch mechanics, a rigid palatal bar fabricated in the laboratory with 1.2 mm wire was used for anchorage. On the bands, triple tubes were placed to allow the use of a cantilever in conjunction with the main leveling wire, which presumably would be used. In addition, a bracket was bonded to tooth #22 (standard Edgewise bracket) to enable control of this tooth during the same treatment period. It was decided that it would be necessary, as well as pulling the canine, to change the position of tooth #22 to enable the traction of tooth #23.

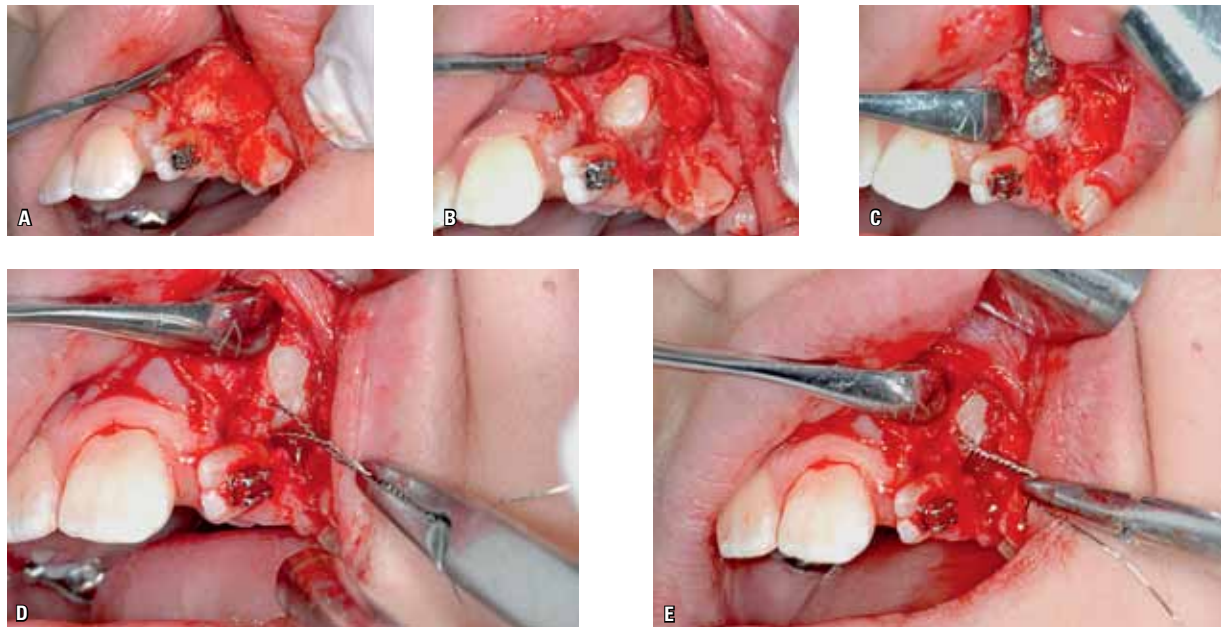


FIGURE 23 - The surgery was performed in strict compliance with the protocol presented in this article. A flap was made on the buccal side (A), with subtle and necessary exposure of the incisal third of the crown of tooth #23 (B), allowing access by drilling at the exact desired spot on the incisal surface, thereby enabling a strategy to achieve maximum traction efficiency. Note how the drilling is minimal (C). The ligature (0.30 mm / 0.12-in thickness) is inserted into the perforation (D) and is carefully twisted (E) so as not to fracture the enamel on the incisal portion. Note the convenient access to tooth #23 and the excellent view of the inadequate relationship between this tooth and the lateral incisor, confirming the etiology of this tooth's malposition (B).



FIGURE 24 - Immediately after the suture, last phase of the access surgery, a TMA rectangular 0.019 x 0.025-in wire segment was adapted to start moving the canine with the foremost intent of removing it from its position over the root of the lateral incisor (outward and slightly downward, oblique direction labially and incisally).

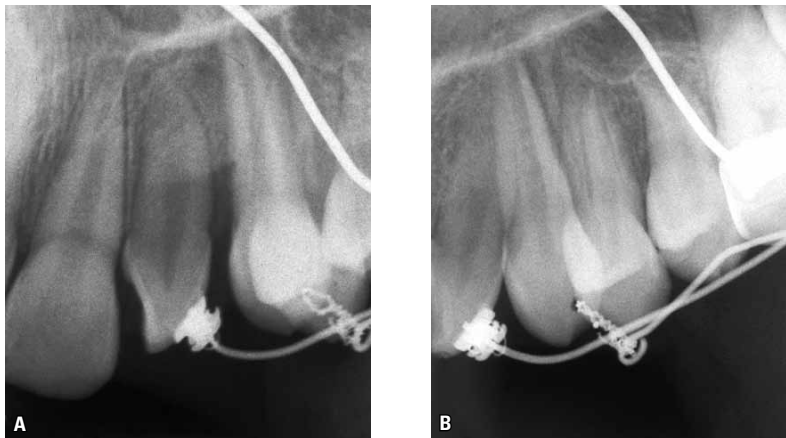


FIGURE 25 - Action on tooth #22 was postponed until the position of the canine allowed it. When this eventually occurred the canine was already in the mouth, in a higher position than would have been the ideal, but in this case mandatory to enable handling the lateral incisor. Another wire segment with the same specifications adopted for canine traction was adapted to move tooth #22. The initial intention was to upright the root of the lateral incisor. Note the radiographic image at this stage with tooth #23 still being moved, supported by the ligature inside the perforation, three months after initiating mechanical traction.



FIGURE 26 - Note how the canine, having had the perforation repaired, also received a bracket to allow palatal torque to be applied on the crown, since by this stage the root of tooth #22 had created enough space for this purpose. Radiographs obtained seven months after the surgical procedure and early canine traction show that these goals were achieved.



FIGURE 27 - Clinical observation disclosed that issues regarding the gross malpositioning of teeth #22 and #23 had been addressed and it seemed reasonable to discontinue the movement. This decision was grounded in the hope that the final eruption of tooth #23 could be better managed spontaneously, since the position of this tooth in relation to the attached gingiva was critical while there was less available space than desired. In short, this decision was based on the key concept underpinning the team's clinical practice, i.e., the desire for orthodontics to be minimalistic.⁶ After all, should the eruption complete its course, the space required to position this tooth as well as the other teeth will be provided by proper handling of the fixed orthodontic appliance.



FIGURE 28 - The outcome was satisfactory and, within the context, considered likely. After ten months deploying the mechanics to correct the malposition of teeth #22 and #23, a case of moderate complexity emerges to be treated with a fixed orthodontic appliance. Effects resulting from the poor positioning of tooth #22 and resolution of problems regarding the eruption of tooth #13, which were minor, and tooth #23, which were serious, and if not eliminated by an interceptive and preventive approach, would result in a severe malocclusion, which would require measures likely to cause tooth loss.



FIGURE 29 - After an eighteen-month treatment with a fixed appliance, the final panoramic radiograph shows adequate and symmetrical root positioning, attesting to the biological efficiency of the suggested protocol for traction of impacted teeth, in this case somewhat undermined by an inadequate relationship between teeth #22 and #23.



FIGURE 30 - The final outcome is a high quality occlusion attained through a simple, conventional orthodontic treatment. With that image in mind, considering the set of advantages offered by this therapy, how can anyone be concerned about drilling a canine?

CLINICAL CASE 3

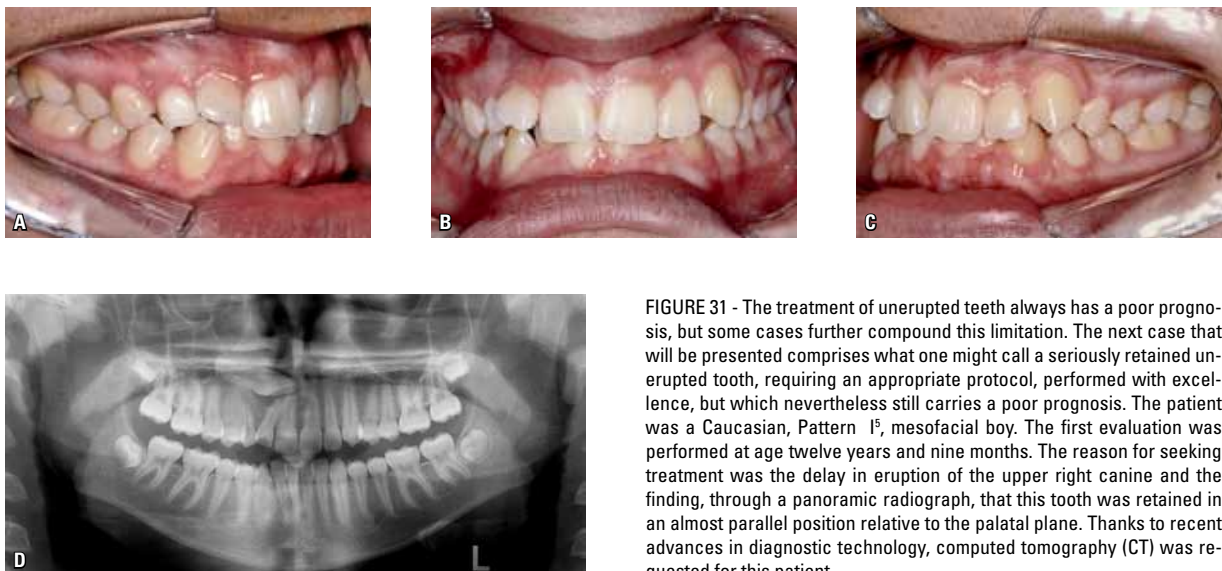


FIGURE 31 - The treatment of unerupted teeth always has a poor prognosis, but some cases further compound this limitation. The next case that will be presented comprises what one might call a seriously retained unerupted tooth, requiring an appropriate protocol, performed with excellence, but which nevertheless still carries a poor prognosis. The patient was a Caucasian, Pattern I³, mesofacial boy. The first evaluation was performed at age twelve years and nine months. The reason for seeking treatment was the delay in eruption of the upper right canine and the finding, through a panoramic radiograph, that this tooth was retained in an almost parallel position relative to the palatal plane. Thanks to recent advances in diagnostic technology, computed tomography (CT) was requested for this patient.

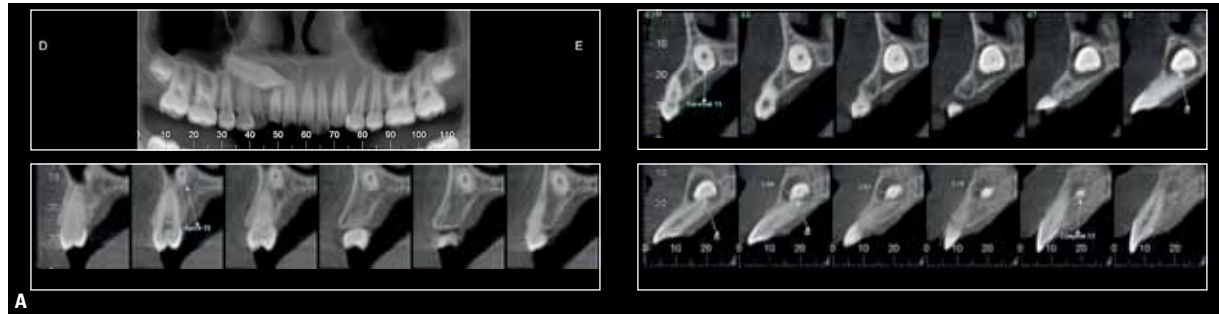


FIGURE 32 - The quality of the images produced by CT are nothing short of impressive. Position of tooth #13 and the relationships it has with the neighboring teeth, specifically with the lateral incisor (A). This allows one to define the strategy and proper approach to perform traction. Thanks to the CT image reconstruction in 3D (B, C), it becomes obvious that the canine cannot be pulled towards the palate given its relationship with the apical region of tooth #22. With this prospect, the treatment can now be fully customized for the patient, including surgical approach and direction of traction.



FIGURE 33 - Given the fact that it provides bone in the anterior maxilla, rapid maxillary expansion (RME) is the standard for treating impacted canines in young patients. As already highlighted before, enough space beyond what is absolutely necessary to accommodate the canine seems to be a mandatory condition to ensure success in this endeavor. Rapid maxillary expansion was performed using a Haas expander, with a triple tube on the band of tooth #16 (A, B), allowing the mesial migration of the anterior teeth toward the midline, an area where new bone is formed after maxillary expansion.

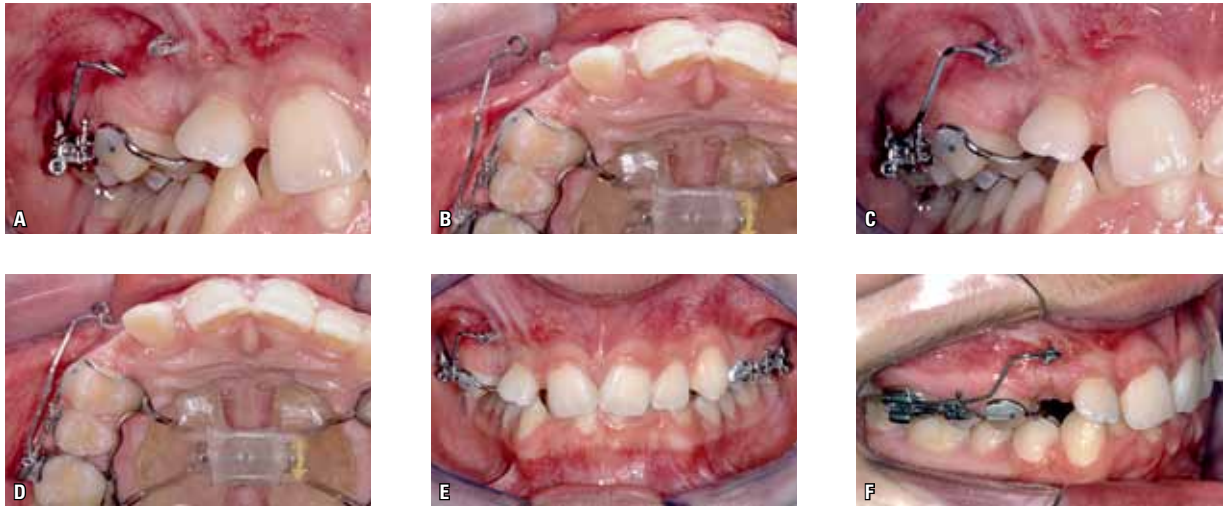


FIGURE 34 - Thus, the buccal traction of the canine with the cantilever – a strategy adopted to move the crown of the canine from a position in which it compresses the lateral incisor root – is enhanced. Note the images of the active cantilever prior to being inserted for canine traction (**A, B**) and the cantilever after insertion in the canine hook (**C-F**) activated for buccal movement, supported by the triple tube on tooth #16 and anchored to the Haas expander structure.



FIGURE 35 - Realizing that the tooth that needs to be pulled should avoid obstacles on its pathway to the alveolar bone is yet another crucial factor in this treatment protocol. A follow-up X-ray six months into treatment shows this movement is still occurring.

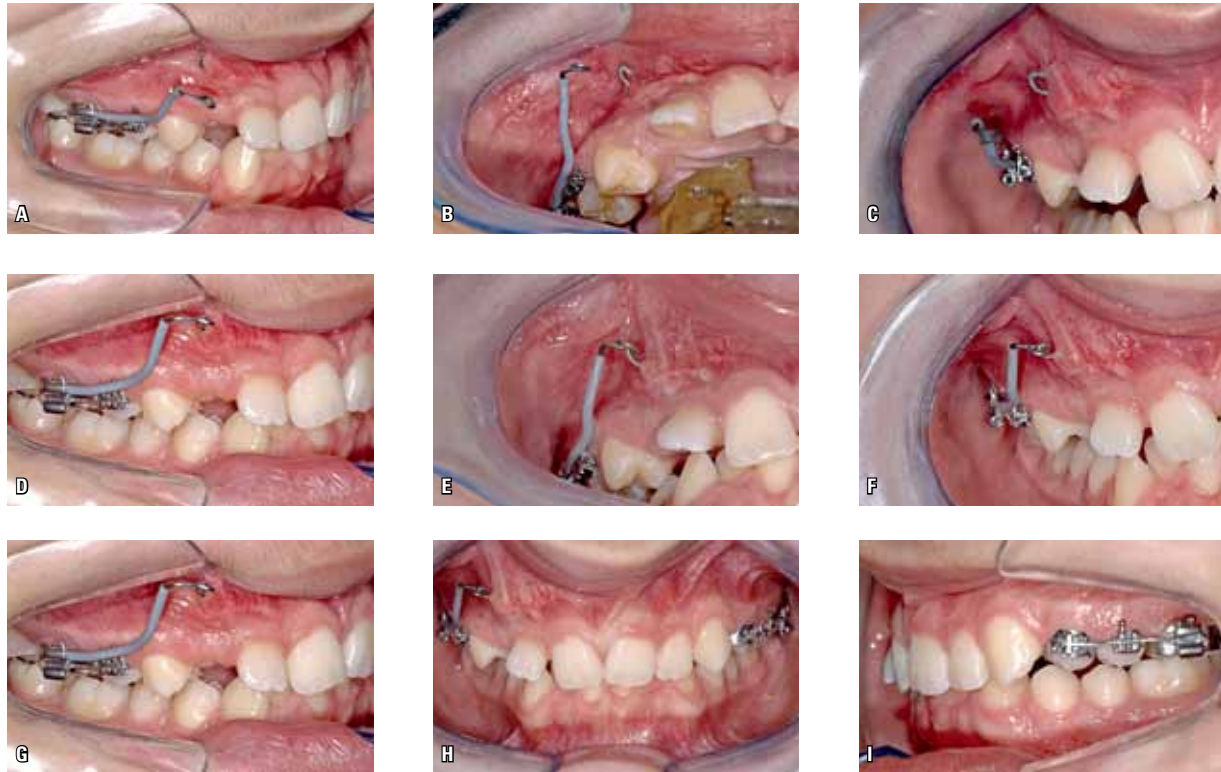


FIGURE 36 - The progress of this movement, which aimed to prevent the canine from impacting the lateral, was completed after nine months of treatment. Note the improvement in the position of the lateral incisor crown (B). At this point, the direction of traction changes while retaining the buccal vector, but now occlusally (A, B, C). The expander continues to provide anchorage and it should therefore be stiff enough to play this part with reliability. Such stiffness – which might otherwise be useful within a general context – is not desirable for tooth #14 since it is adjacent to the movement area and cannot withstand minor movements caused by the canine on being pulled mesially into the bone. For this reason tooth #14 – which was not banded in keeping with the protocol used by the authors' team when fabricating the Haas appliance – was released from the expansion appliance at this stage.

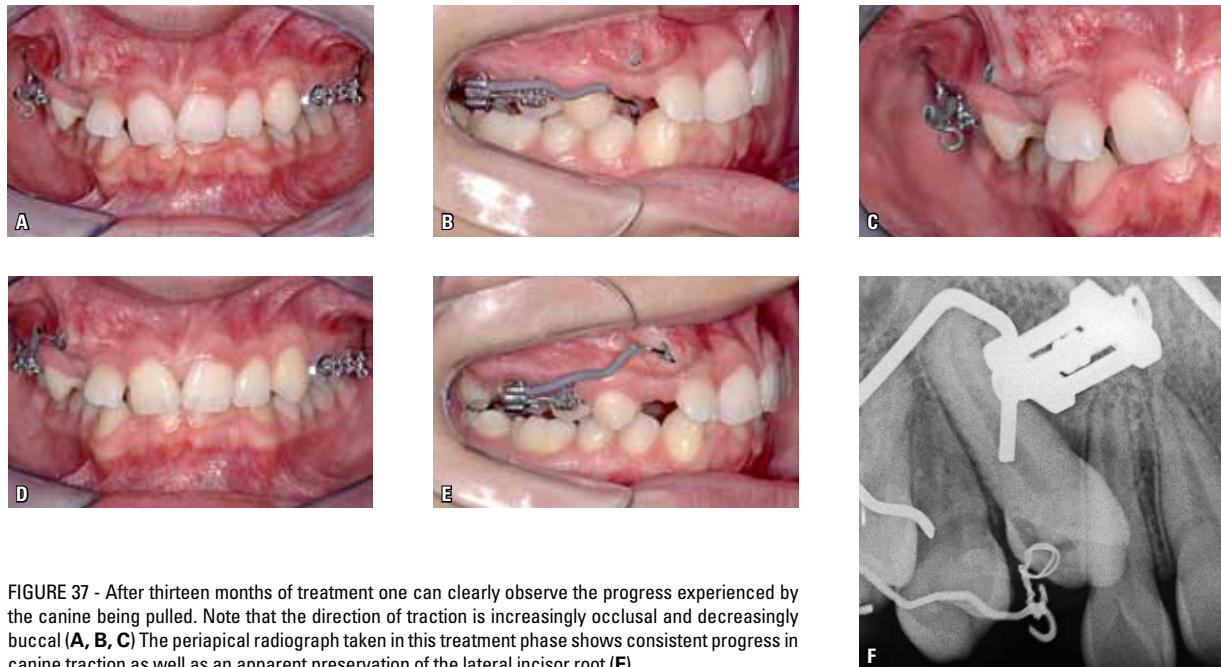


FIGURE 37 - After thirteen months of treatment one can clearly observe the progress experienced by the canine being pulled. Note that the direction of traction is increasingly occlusal and decreasingly buccal (A, B, C). The periapical radiograph taken in this treatment phase shows consistent progress in canine traction as well as an apparent preservation of the lateral incisor root (F).

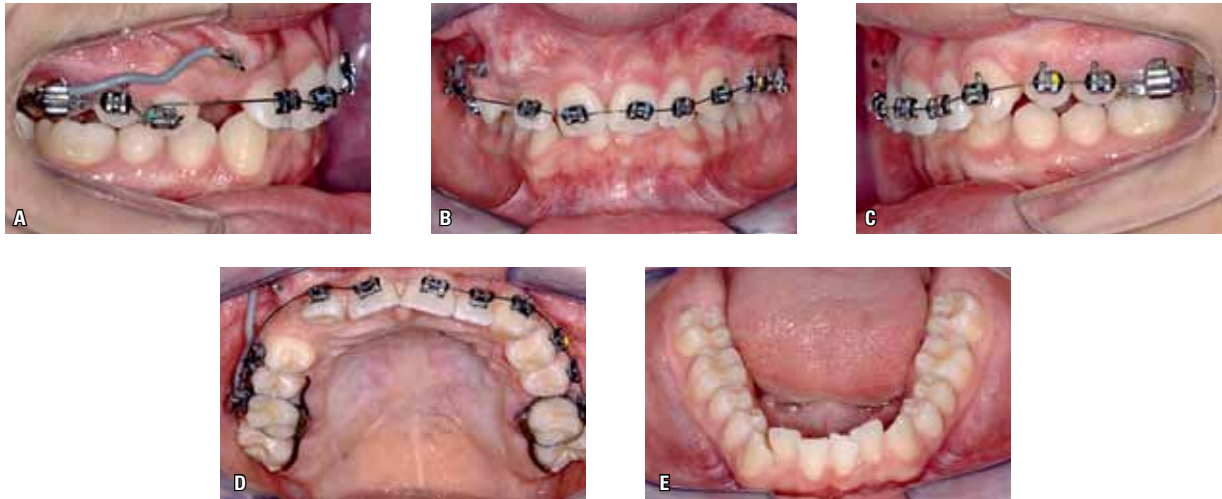


FIGURE 38 - In this phase, considering the occlusion as a whole and, at the same time, the need to create space in the area with a view to completing the canine traction, the expansion appliance was removed and a fixed orthodontic appliance placed. The treatment was started in the upper dental arch in compliance with the protocol used in a patient with bimaxillary retrusion – causing overbite and crowding – with the purpose of deliberately causing protrusion.^{5,6} Moreover, this can ultimately benefit traction. This is but an overview. However, some details regarding the latter can prove critical, hence the primary goal of this treatment. Note also that the teeth present in the neighborhood of the space created for tooth #13, which is under traction, are managed in very specific ways. Tooth #14 was treated with segmented mechanics using a rectangular wire to position its root in such a way as to not affect the crown of tooth #13, and received the bracket meant for tooth #13. By the same token, tooth #12 received an inverted bracket (the bracket for tooth #22 was bonded to it), thereby reversing the mesial nine-degree angulation and keeping the mesial root angulation.

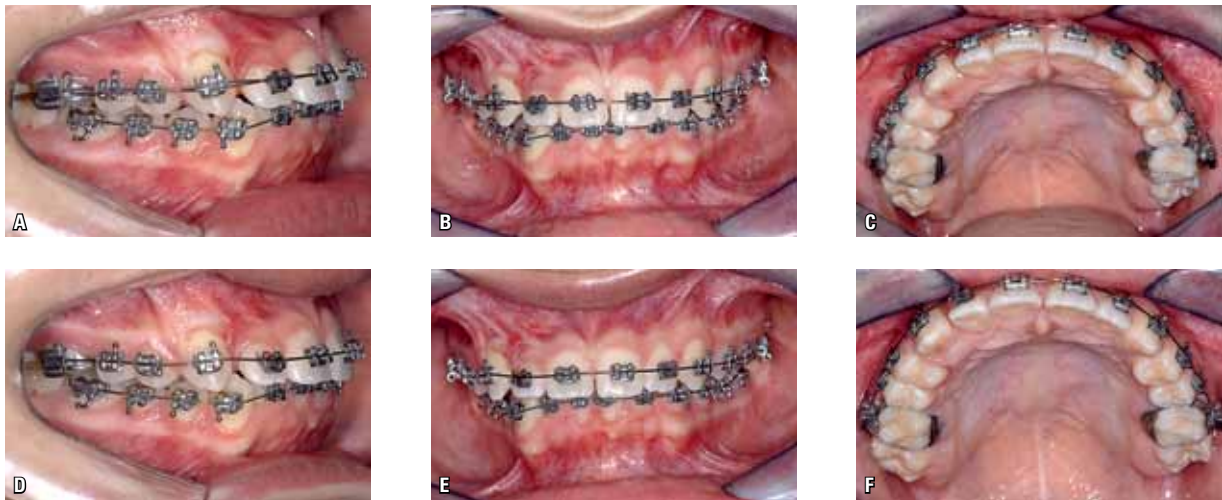


FIGURE 39 - Finally, eighteen months into treatment, tooth #13 occupies the space designed for it on the alveolar ridge after having been rescued from the atypical position it formerly occupied. Note that tooth #13 is being leveled with an overlay arch mechanics with the aim of minimizing side effects in adjacent teeth (A, B, C). At this stage, the bracket on tooth #12 was replaced by a conventional bondable bracket and a 0.016-in steel wire was inserted (D, E, F). Note that tooth #13 was bonded with the bracket designed for tooth #23 to generate a mesial root movement (A-D).

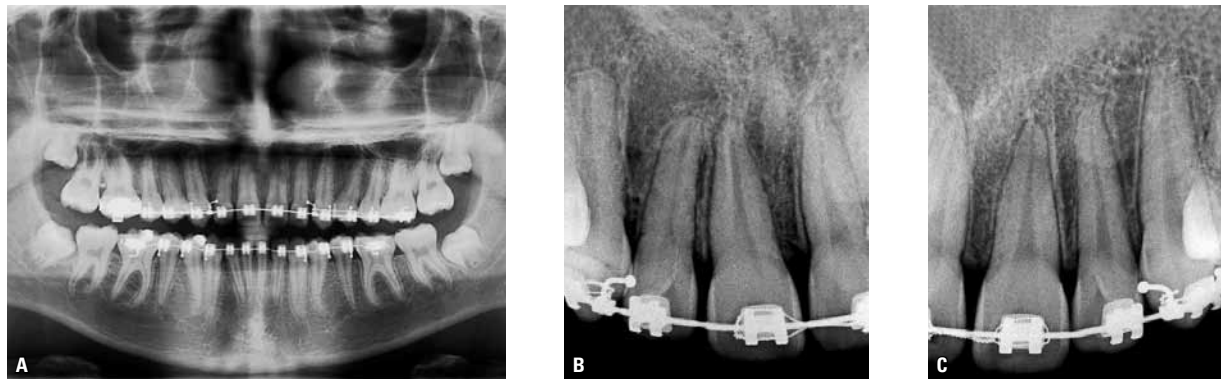


FIGURE 40 - Panoramic and periapical radiographs taken for the final evaluation attest to the quality of the results. The view of the dental arch in the panoramic radiograph shows a remarkable symmetry of tooth position, considering the original positions (A). A comparison between lateral incisors and canines shows the sequelae resulting from the extensive movement experienced by teeth #12 and #13 (B, C). The apical resorption of tooth #12 was greater than 1 mm and less than 2 mm, while that of tooth #13 was greater than 2 mm and less than one apical third. It can be assumed that such loss will not prevent anyone from considering this treatment not only justifiable but successful.

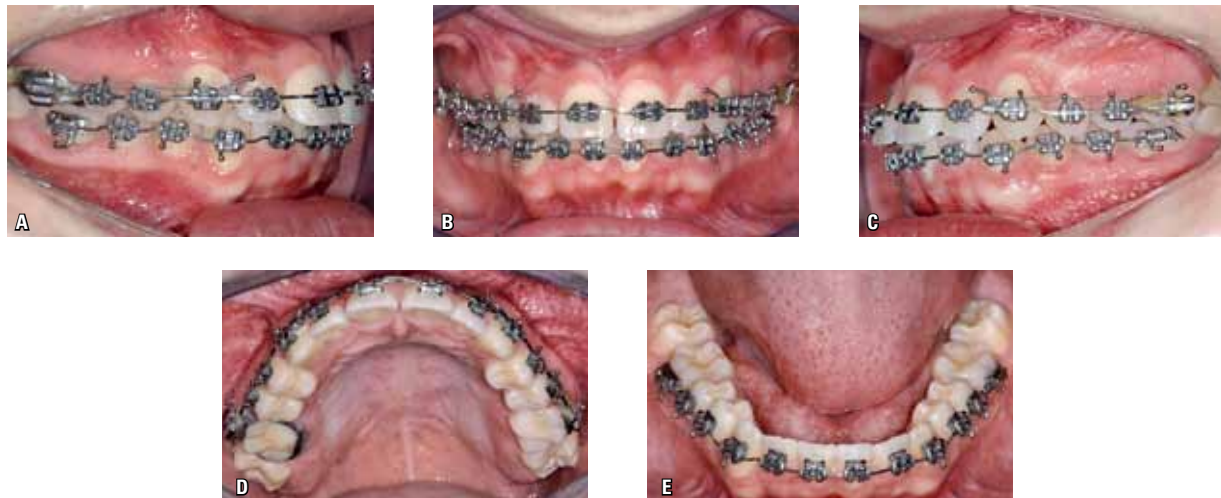


FIGURE 41 - Final intraoral photographs of the patient's occlusion in the finishing phase just before removal of the appliances. Clinically, this is a very consistent outcome made possible by a protocol that defines the primary actions described earlier in this article, and specific actions for each case. Customization is a set of actions designed specifically for a given patient.⁶

ENAMEL DRILLING FOR CANINE TRACTION (EDCT) TECHNIQUE: STEP BY STEP

The EDCT technique has always been the first therapeutic option embraced by the authors' team. This procedure has been performed as a protocol for canine traction for over 30 years. This surgical technique involving drilling of the crown of the unerupted canine (EDCT) was first carried out in the mid-80s by Prof. Dr. Reinaldo Mazzottini in patients with cleft lip

and palate at the HRAC-USP/Bauru hospital, Brazil, and later performed in patients in the authors' private practice.

The surgical technique involves exposing the canine crown enough to bore a small hole in it with a small diameter ($\frac{1}{4}$ ") spherical carbide bur. Drilling should be performed with extreme care so as not to encroach on the pulp chamber.³¹ The diameter should be sufficient as to allow the passage of a folded ligature wire (0.30 mm / 0.12-in).

The drill should bore a hole into the crown of the unerupted canine always perpendicularly to the long axis in order to prevent the bur from approaching the dental pulp. This orientation is not always easy in view of the position of the canine, and requires an experienced surgeon.

Another crucial point is that after passing the folded ligature through the hole in the crown, attention should be paid when twisting the ligature wire. An instrument – most commonly an

explorer probe – must always be interposed between the ligature wire and the tooth enamel in order to avoid enamel fracture, which might prompt the need to repeat the drilling.

In this topic, the EDCT surgical technique will be shown step by step using a patient with an indication for traction of teeth #13 and #23, where access and preparation for traction on both unerupted canines was performed in the same surgical procedure.

CLINICAL CASE 4



FIGURE 42 - Intraoral photographs (A-E) supplemented by images of panoramic radiograph (F) and periapical radiographs of the upper incisors (G, H) in a young patient (aged fourteen years and five months), Short Face-borderline Pattern I⁵. In permanent dentition and Class I occlusal relationship (bilateral), the panoramic radiograph (F) revealed that teeth #13 and #23 were impacted, which had motivated the initial consultation, and teeth #53 and #63 were retained.



FIGURE 43 - After banding the first permanent molars and taking a working impression, a palatal bar was fabricated from 1.2 mm wire to increase anchorage and, consequently, avoid side effects in the maxillary first molars. The transpalatal arch and the upper teeth brackets were bonded. On the same day the patient was referred to the surgeon to perform the extraction of teeth #53 and #63 and be prepared for access to and traction of teeth #13 and #23 through the alveolar region.



FIGURE 44 - The surgical procedure was started with infiltration anesthesia in the buccal region of tooth #13 and blocking of the nasopalatine nerve lingually. A mucoperiosteal flap was folded down from the mesial side of tooth #11 and mesial side of tooth #14, enough to expose a small portion of the crown of tooth #13 (A). Tooth #53 was extracted and tooth #13 exposed through the removal of bone tissue with a spherical steel bur under copious saline irrigation, always taking care to avoid handling the dental follicle (B) as much as possible.



FIGURE 45 - Drilling of tooth #13 was performed perpendicular to the long axis of the tooth with a small diameter ($\frac{1}{4}$ ") high speed bur and copious irrigation. This is important to prevent the bur from reaching the pulp chamber, thereby causing irreversible pulpitis or even requiring endodontic treatment. The competence and experience of a professional surgeon is of paramount importance to avert such damage. A stronger ligature wire (0.30 mm / 0.12-in) was used to minimize the risk of breakage, which might entail the need to reopen the wound. The ligature was inserted in the perforation and twisted with a Mathieu plier (B). Carelessly twisting the ligature without seeing to it that the explorer probe tip is safely inserted between the ligature and the canine can cause enamel fracture and require new drilling, further increasing the biological cost of the procedure (C).



FIGURE 46 - In a similar manner on the contralateral side, the surgical procedure was continued with buccal infiltration anesthesia in the region of tooth #23. A mucoperiosteal flap was folded down from the mesial side of tooth #21 and the mesial side of tooth #24, enough to expose a small portion of the crown of tooth #23 (A). Tooth #63 was extracted and tooth #23 exposed in similar manner as tooth #13, by avoiding as much as possible manipulation of the dental follicle (B).



FIGURE 47 - Drilling of tooth #23 was performed according to the same protocol adopted for tooth #13, i.e., using high speed bur with copious irrigation, perpendicular to the long axis of the tooth, with a carbide bur of small spherical diameter ($\frac{1}{4}$ " (A). The ligature wire was inserted into the perforation and after passing through it, was twisted with a Mathieu plier (B). The tip of an explorer probe was placed between the ligature and the canine (C).

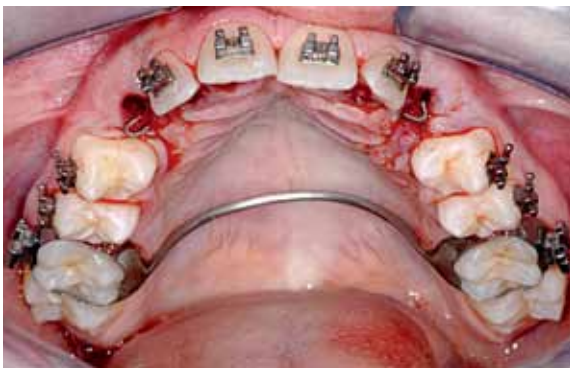


FIGURE 48 - The surgical procedure was completed through bilateral suturing and final adjustment of the ligature wire, which is bent back in the form of a hook while any jutting edges are cut off to avoid hurting the patient. Still under the effects of local anesthesia, the patient returned and a leveling 0.014-in Nitinol archwire was inserted between tooth #16 and tooth #26.



FIGURE 49 - TMA 0.019 x 0.025-in wire segments were placed in the auxiliary tubes of teeth #16 and #26 in order to pull teeth #13 and #23 in the occlusal and distal direction with the purpose of preventing contact between canines and adjacent lateral incisors. In addition to the direction of traction, it is crucial to measure the intensity of the traction force in moving the canines, always ensuring a magnitude between 35 and 60 grams.²⁵ Note in the intraoral photographs (A, B, C) the cantilevers already positioned in the auxiliary tubes with the activation required for traction, but not yet attached to the hooks fabricated with the ligature wires inserted in the perforations of teeth #13 and #23.



FIGURE 50 - Intraoral photographs (A, B, C) showing active TMA wire segments tied to the hooks made with the ligature wires inserted in the perforations drilled into teeth #13 and #23.

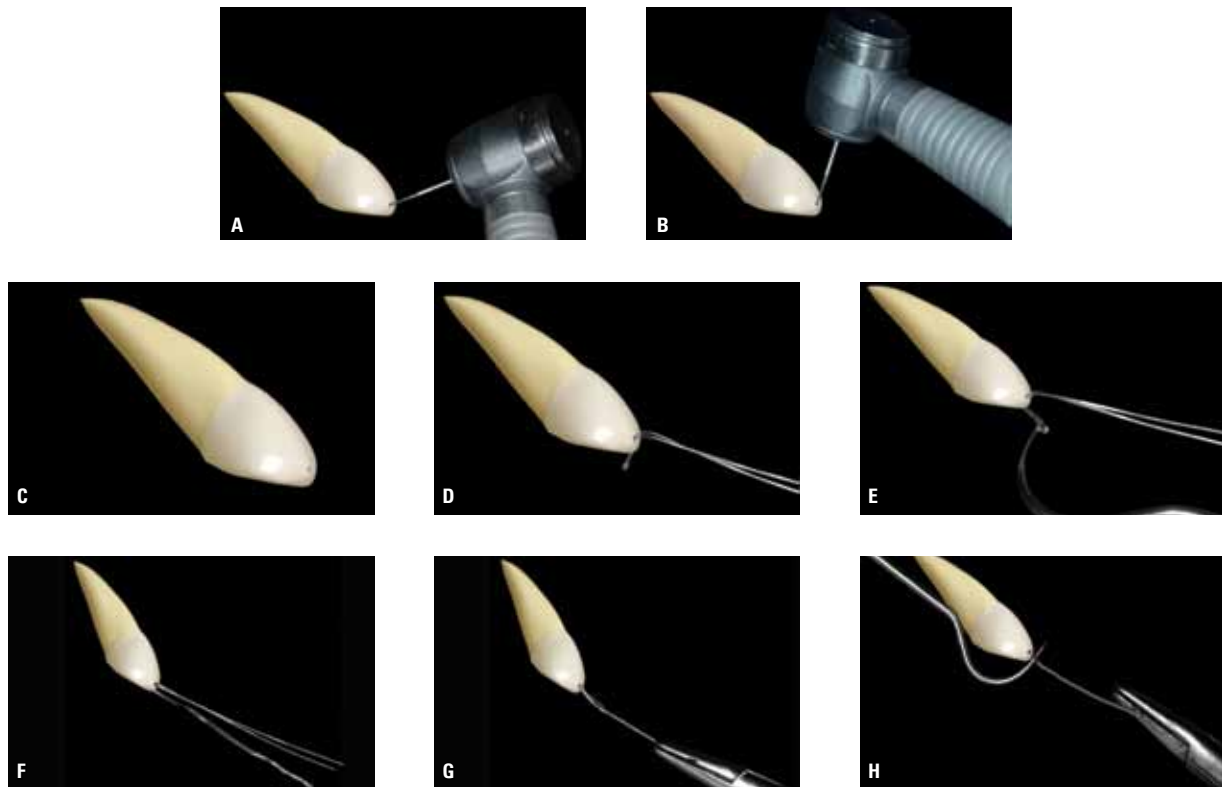


FIGURE 51 - Drilling of the canine should be performed by means of high speed with copious irrigation, perpendicular to the long axis of the tooth and using a spherical carbide bur with a small diameter ($\frac{1}{4}$ ""). Note the incorrect insertion of the bur (A) and the proper insertion (B), perpendicular to the long axis of the unerupted canine. This is important to prevent the drilling from reaching the pulp chamber, causing irreversible pulpitis, or the need for endodontic treatment. After drilling the canine (C) with a diameter sufficient as to allow passage of the folded ligature wire (0.30 mm / 0.12-in), the latter is inserted into the perforation (D) aided by the tip of an explorer probe (E). Passing the folded ligature through the perforation enables greater protection against potential fractures (F), when the twisting motion is initiated (G), always at the end of this movement by interposing the tip of an explorer probe between the ligature and dental enamel (H) in order to avoid fracture of the enamel and the consequent need for new drilling.

EDCT BIOMECHANICS

Orthodontic traction is intended to redirect the eruption pathway and assist or even replace the eruption force of the unerupted tooth.¹² It consists of an extrusive tooth movement and, as such, is determined by the periodontal ligament and its cells.¹⁸ Although it is a safe and effective procedure in clinical practice it should only be performed based on biological and up-to-date scientific knowledge. When performed with controlled forces and movement, the pulp is not affected and the odontoblasts remain unscathed and do not cause internal resorption.^{7,13}

When the pathway of an unerupted tooth compresses the vessels of the periodontal ligament of adjacent teeth – with or without orthodontic traction – cementoblasts die on the spot and the root is resorbed to give rise to the follicle and its moving crown. By redirecting the eruption pathway of the unerupted maxillary canine and/or the growth vectors involved in the process, tooth root resorption will cease in neighboring teeth and the surface will be repaired with new cementum and cementoblasts. Extraction of the unerupted tooth triggers a process of regression and re-covering of

the resorbed area by new cementoblasts, with deposition of a new layer of cementoblasts and reattachment of periodontal fibers.^{14,15}

Thus, it is advisable to increase the space between the teeth in the upper arch so that the unerupted tooth can lodge itself in the area enclosing the DF and its crown. For the purpose of having a measurable parameter, it is recommended that the mesiodistal distance from the canine crown be calculated and the result multiplied by 1.5. This is not always possible from a clinical point of view, but the use of this criterion and measurement represents a starting point for decision making relevant to each case.^{14,15} Often, this space cannot be obtained. An alternative that might prevent this inconvenience is to divert the eruption pathway of the canine undergoing traction to a site outside the region of conflict with the roots of adjacent teeth. In canines retained on the palate side, this procedure can be performed, whereas canines retained on the buccal side can hardly benefit from this maneuver. The deciding factor in rendering this procedure practicable is the extensive area of attached gingiva provided by the palate, in contrast to a scarcity of attached gingiva on the buccal side.

Since the DF is comprised of soft tissues, it may be physically compressed between the canine crown and the roots of the lateral incisor and first premolar, but performing this maneuver during traction may result in the lateral resorption of these roots. The opening of space or, as seen above, a temporary change in the eruption pathway eliminates compression of the periodontal ligament of adjacent teeth while cementoblasts and cementum re-cover the roots of these teeth. The DF of the unerupted tooth is farthest from the root surface and its mediators no longer act as enhancers of dental resorption, but rather only stimulate pericoronal bone resorption to enable the eruption to take place in the desired pathway. By moving

an unerupted canine through orthodontic traction, whenever possible, the dental follicle is also moved away, which is usually sufficient to stop root resorption and repair the surface.^{14,15}

The mechanics of choice for unerupted canine traction should be fully tailored to suit each individual. Thus, straight wire mechanics, admittedly ineffective in this regard, should be avoided for this purpose. Whenever segmented mechanics is employed to enable the mechanical traction of an unerupted canine, movement control becomes much more efficient, with greater control over side effects and reduced need for appliance activation.²⁹

These factors together greatly reduce the risk of resorption of the teeth adjacent to the unerupted canine by completely individualizing the direction of traction. This resorption is certainly one of the orthodontists' greatest fears in carrying out this procedure, which often leads them not to generate these forces for fear of resorption, especially in the lateral incisors. Clinicians with no experience in these movements often discontinue the process for fear of not being able to observe the intraosseous canine, with negative impact on the movement of traction.

The traction force should be continuous and measurable. The amount of force indicated for anterior teeth, according to Graber and Vanarsdal,²⁵ should be between 35 and 60 grams, similar to the movement of the erupting canine. It should be slow and continuous to allow adjacent tissues to accompany the movement, avoiding interruptions during this process. This amount of force must be measured using a quality tension gauge, with enough sensitivity to measure small amounts of force, such as reported above.

Furthermore, inducing stronger forces can partially damage or tear and rupture the apical neurovascular bundle that enters the root canal, causing calcium metamorphosis of the pulp and aseptic pulp necrosis, respectively.^{18,19} The induced tooth movement resulting from

traction of the unerupted maxillary canines – an extrusive movement – must have forces that are delivered and dissipated slowly, consistent with normal biological tissue. Connective and epithelial tissues are constantly remodeling, which gives them remarkable ability to adapt to new functional demands.^{16,17}

Sometimes, depending on the original position of the canine and the pathway set for its traction, the force required could be greater than that used only to trigger the movement of the unerupted tooth, which copies the movement of eruption. Translation (bodily) movements are often needed, and considering the range of movement, forces of greater magnitude may be necessary. They must be defined in line with those that would be necessary for it to move with the erupted tooth in its socket.

To obtain low-intensity, continuous forces, technological advances now allow orthodontists to work with good quality resilient wires with moderate formability, which enables the placement of first, second and third order bends. Beta-titanium or titanium-molybdenum (TMA) wires feature half the stiffness and hence double the resilience when compared to steel wires of the same cross section. Moreover, these wires preserve activation for a longer period of time. Frequent activations are no longer necessary and continuous forces are maintained. In addition, one should work with the greatest possible distance between molar tube and canine in order to increase the cantilever and decrease forces.²⁷

In orthodontic traction the bundles of periodontal fibers, which are usually inclined toward the apex – from the fascicular bone toward the cementum – are stretched in the occlusal direction and reverse this inclination. Compression of vessels and cells will be small but sufficient to generate mediators that promote bone resorption in the periodontal surface and reattachment of Sharpey's fibers in new positions. In the apical region during orthodontic traction, fiber stretching occurs

nearly parallel to the long axis of the tooth and the amount of mediators released by the cells amid fibers and extracellular matrix fibers tends to be slightly higher than normal: Apposition due to new bone formation will be almost immediate.¹⁶

When the TMA wire is inserted into the auxiliary tube of the first permanent molar and the other end is inserted more occlusally in relation to the unerupted canine, this force has an extrusive component that causes a reaction in the anchorage molars, i.e., a mesial angulation movement of the crown and distal movement of the root, with a tendency toward mesial intrusion. The canine moves occlusally and tends toward lingual inclination of the crown and buccal inclination of the root as a result of the buccal force relative to the center of resistance of the canine.²⁹

In an attempt to minimize side effects during the movement of traction of the canine, the use of an efficient anchorage system is indicated. In such cases, one should opt to use a welded transpalatal bar with large diameter wires (1.0 to 1.2 mm). Adapted bars should be avoided in these situations because there is some slack between the lingual tube and the palatal bar, which minimizes the control of side effects by allowing greater movement of the anchorage molars.

Even with the use of palatal bars fabricated with large diameter wires, the side effects are never fully controlled, but minimized. Whenever possible, one should band first molars with triple tubes to perform traction supported on the auxiliary first molar tubes, so that the anchorage is enhanced by including these teeth in the upper leveling, with the large caliber leveling arch passing through the main tube.

In cases where maxillary expansion is indicated, a Haas-type expander offers an excellent anchorage choice in view of the ruggedness of these expansion appliances. The segmented arches used in traction can be anchored on the tubes welded to the first molar bands or on the acrylic portion of the expander.

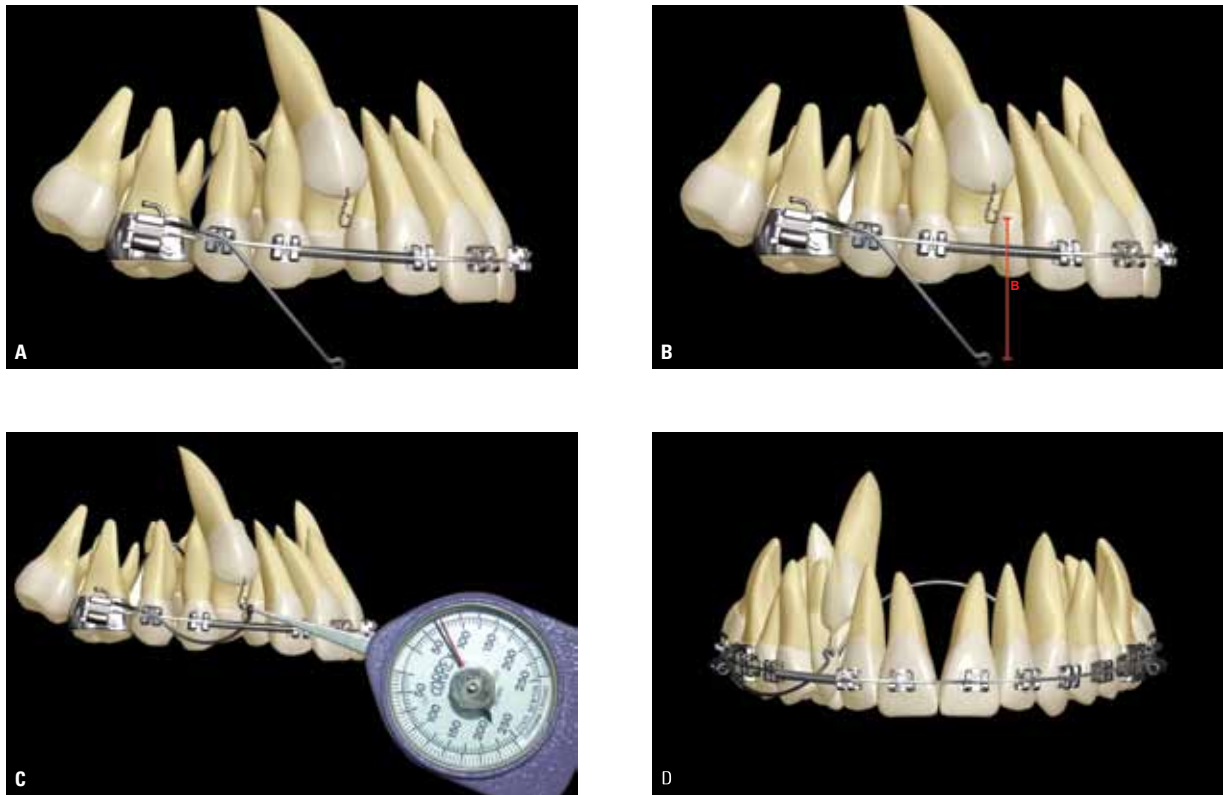


FIGURE 52 - Lateral images illustrating traction of an unerupted canine (tooth #13) by means of straight wire mechanics, with total leveling of the upper dental arch, except for tooth #13, indicated for traction through segmented arch mechanics. The access procedure and preparation for traction had already been performed by the EDCT technique. Anchorage is accomplished with the aid of a transpalatal bar welded with a large diameter wire (1.0 to 1.2 mm) with the intent of minimizing side effects in anchorage molars when pulling an unerupted canine. Tooth #16 is banded with a triple tube, which has two rectangular tubes, one being used for leveling, while the other tube, positioned more cervically, is used for insertion of a TMA 0.019 x 0.025-in wire. At this stage, leveling involves the use of a rectangular 0.019 x 0.025-in steel archwire with an open coil spring placed between teeth #12 and #14, with the aim of maintaining or creating space for canine traction. To illustrate the sequence: Cantilever in position, not yet activated (A); the amount of force is measured from the end of the TMA wire to the surgically accessed canine ligature (B); the use of a tension gauge to measure the force with enough sensitivity to detect low intensity forces, which according to Graber and Vanarsdall²⁵ must range between 35 and 60 grams (C); the movement to pull tooth #13 was initiated by a mechanics that allows individualized control of the targeted teeth while mitigating side effects in adjacent teeth. These are essential conditions for the traction of unerupted canines, something a straight wire mechanics would never have allowed. When the cantilever is activated, it generates an extrusive force on the unerupted canine and an intrusive force on the upper first molar, resulting in distal angulation of the root and mesial angulation of the upper first molar crown (D).



FIGURE 53 - Occlusal images of the mechanics used to buccally move the unerupted tooth #13. To illustrate the sequence: Cantilever in position, not yet activated (A); the movement of traction of tooth #13 was initiated buccally, with the forced measured with the aid of a tension gauge (B). When the cantilever is activated, it delivers a lingual force to the upper first molar and labial force to the canine, resulting in a mesiolingual rotation of the upper first molar crown (C).

FINAL CONSIDERATIONS

Clinical experience, cost-effectiveness analysis and the level of risk involved in the traction of unerupted permanent canines led the authors to conclude that the EDCT protocol is more suitable than the ABCT protocol.

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Yours sincerely,

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