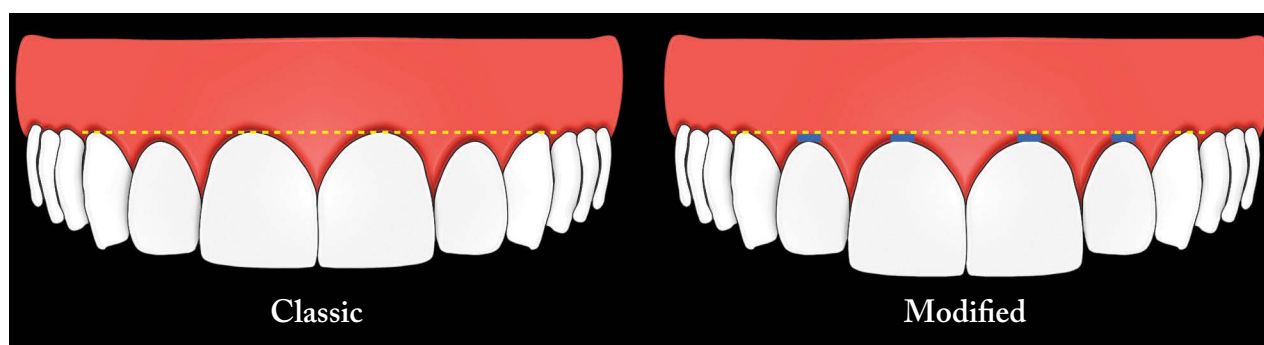


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Volume 19, Number 4, July / August 2014



Official Journal of the Brazilian Association of Orthodontics and Facial Orthopedics

Official Journal of the Brazilian Board of Orthodontics



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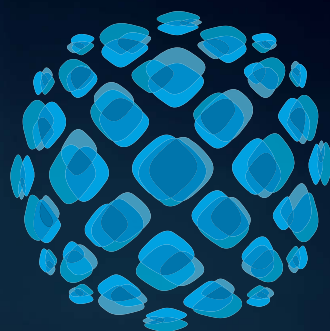
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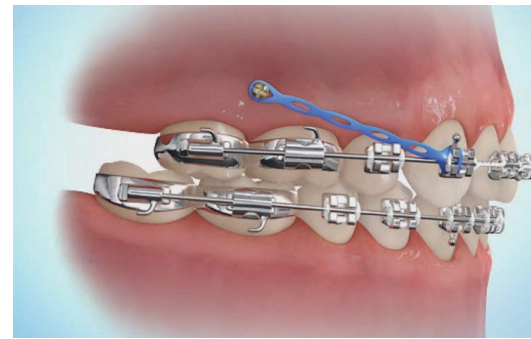
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¹ Siqueira M.R., Stanislawczuk R., Kossatz S., Reis A., Loguerio A.D. Avaliação Clínica de uma Resina Autoadesiva para Colagem de Bráquetes Ortodônticos. Ortodontia SPO, v. 44, n.5, p. 435-441, 2011.



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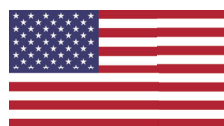
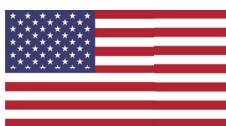
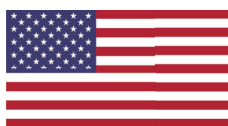
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31/10/2014



09:00 ÀS 10:00

INVISALIGN - ORTODONTIA E TECNOLOGIA

PALESTRANTE:
MAURICIO CASA (SP)



10:00 ÀS 11:00

PLANEJAMENTO ESTÉTICO EM ORTODONTIA:
UMA NOVA VISÃO E UMA NOVA
PERSPECTIVA

PALESTRANTE:
CARLOS ALEXANDRE CÂMARA (RN)



11:00 ÀS 12:00

LIMITES DA ORTODONTIA

PALESTRANTE:
WEBER URSI (SP)



14:00 ÀS 15:20

MINI-IMPLANTES ORTODÔNTICOS: APLICAÇÕES
CLÍNICAS E CONSIDERAÇÕES BIOMECÂNICAS

PALESTRANTE:
CARLO MARASSI (RJ)



15:20 ÀS 16:40

TÉCNICA DO ARCO SEGMENTADO: APLICAÇÕES
CLÍNICAS DE CANTILEVERS

PALESTRANTE:
ALEXANDRE SIMPLICIO (PI)



16:40 ÀS 18:00

O PLANO DE TRATAMENTO BASEADO EM SEU
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09:00 ÀS 12:00

CONTROVÉRSIAS NA ORTODONTIA

PALESTRANTE:
ALBERTO CONSOLARO (SP)



14:00 ÀS 15:00

TRATAMENTO ORTODÔNTICO DE PACIENTES COM
PROBLEMAS PERIODONTAIS. O AUXÍLIO DO SISTEMA
AUTOLIGADO

PALESTRANTE:
LILIANA MALTAGLIATI (SP)



15:00 ÀS 16:00

AUTOLIGADO COM EXCELÊNCIA

PALESTRANTE:
JURANDIR BARBOSA (SP)



16:00 ÀS 17:00

SISTEMAS AUTOLIGADOS: ESTÁGIO ATUAL

PALESTRANTE:
CLAUDIO AZENHA (SP)



17:00 ÀS 18:00

BRÁQUETES AUTOLIGÁVEIS: QUAL A SEQUÊNCIA
IDEAL DOS ARCOS?

PALESTRANTE:
ALEXANDRE GALLO LOPES (SP)

29/10

A

01/11

CENTRO DE CONVENÇÕES DA BAHIA
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Internationalization

“To have a new language is to have a new soul.”

Juan Ramón Jiménez, Spanish poet.

Globalization and internationalization are terms of the corporate world. In this scenario, mastering the English language is indispensable and with Brazilian science is not different. CAPES (Coordination for the Improvement of Higher Education Personnel) and CNPq (National Council for Scientific and Technological Development) have encouraged postgraduate programs and scientific research to effusively enter into the international scenario. However, the Shakespearean language is the foundation of this building. CAPES and CNPq programs have advanced and are good examples, despite Brazilian one-legged basic education system. Science without Borders is a nationwide scholarship program funded by the Brazilian federal government and is a good example we should be proud of. The program has expanded and, nowadays, includes not only postgraduate, but also undergraduate programs. Nevertheless, supply exceeds demand, especially because most undergraduate and postgraduate students do not master the English language. The solution was to establish the program English without Borders.

With a worldwide, clinically and scientifically, renowned Dentistry, Brazilian journals have increasingly sought internationalization in the counterflow of federal support. Internationalization is, in general terms, the need for communicating in a single language.¹ In Brazilian Dentistry, six out

of the seven journals indexed in SCOPUS are fully published in English. That is how our Dental Press Journal of Orthodontics (DPJO), with an ear to the world, has been disclosed: in English, since 2010, as well as in Portuguese. This is a milestone in the internationalization of this journal which has been sculptured for nearly a decade.

Speaking does not guarantee us to be heard. For this reason, in addition to the need of establishing communication in the language shared by science, it is of paramount importance that the journal content be disclosed. Thus, step-by-step, DPJO was being embraced by the major international databases: SciELO (2005), SCOPUS (2008) and, recently, PubMed (2013). We acknowledge that publishing a journal in a universal language globally increases reader's interest. However, what would be the impact of this process of internationalization on overseas authors?

We are aware that the number of articles written by Brazilian orthodontists published in international journals has increased in the last decades.² Nevertheless, the interest in publishing in Brazilian journals did not follow the same pace. In 2012, when DPJO was not yet indexed in PubMed, only 3% of articles were submitted by foreign researchers. These articles came from India, Malaysia and Iran and did not fulfill acceptable

methodological quality. After being indexed in PubMed, the number of submissions by foreign authors grew dramatically. By analyzing data from the last twelve months (Aug, 2013 – Jul, 2014), we notice that one third of articles submitted to DPJO come from different countries such as Canada, the United States, Italy, Colombia, Pakistan, India, Mexico, Saudi Arabia, Singapore and Iran. An increase that surpasses 1000%. Within this period, DPJO acceptance rate was of 30% for articles submitted by Brazilian authors and 10% for overseas authors. These numbers lead us to infer that not only the amount of articles submitted by overseas

researchers has increased, but also the number of high-quality articles reaching our brooks.

A new language renews the soul and provides those who seek leadership in a high-quality corporate world with courage. Therefore, our young journal has followed the steps of the Spanish poet cited in the epigraph whose exile led him to learn a new communication tool capable of spreading his art throughout the literary world. We go on publishing in the Portuguese language. Thus, we have not renounced the language of Camões, but acquired a new soul instead.

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2. Normando D. The Brazilian dental science. *Dental Press J Orthod.* 2014 Mar-Apr;19(2):14.

Matheus Melo Python*

ASYMMETRIES NOT GREATER THAN 5.6 MM GO UNNOTICED BY LAYPEOPLE

The literature extensively reports the need for a certain degree of asymmetry between the right and left sides of the face, which give facial contour a natural form. Should both sides of the face be completely symmetrical, they give the person an artificial and unpleasant look. Nevertheless, what is the acceptable limit of normal asymmetry? With a view to answering this question, English researchers conducted a study¹ in which they analyze frontal facial photographs of female and male patients (Fig 1) and develop different degrees of asymmetry in the chin area. The same images were analyzed by laypeople, students and professionals of Dentistry, as well as dental-surgeons and orthodontists in terms of perception of different degrees of facial asymmetry in male and female patients. Results revealed that the two major factors influencing perception of asymmetry were the evaluator and the degree of asymmetry. Orthodontists proved much more critical of asymmetry in comparison to laypeople. The more asymmetric was an image, the more noticeable asymmetry was. The research outcomes prove necessary to assess each case individually before referring a patient to surgery.

DENTAL ALIGNMENT IS MORE QUICKLY PERFORMED WITH CONVENTIONAL BRACKETS RATHER THAN WITH SELF-LIGATING ONES

Since the beginning of our specialty, we have experienced an evolution in terms of technique, material and concepts adopted. As in any other knowledge domain, evolution tends to promote improvements in

products and services, thereby making our lives easier. Orthodontic brackets are not different. They stand in the spotlight due to their ligating system, in other words, they have become self-ligating. Undoubtedly, the self-ligating system is beneficial, especially in terms of chair time, as it eliminates the need for using

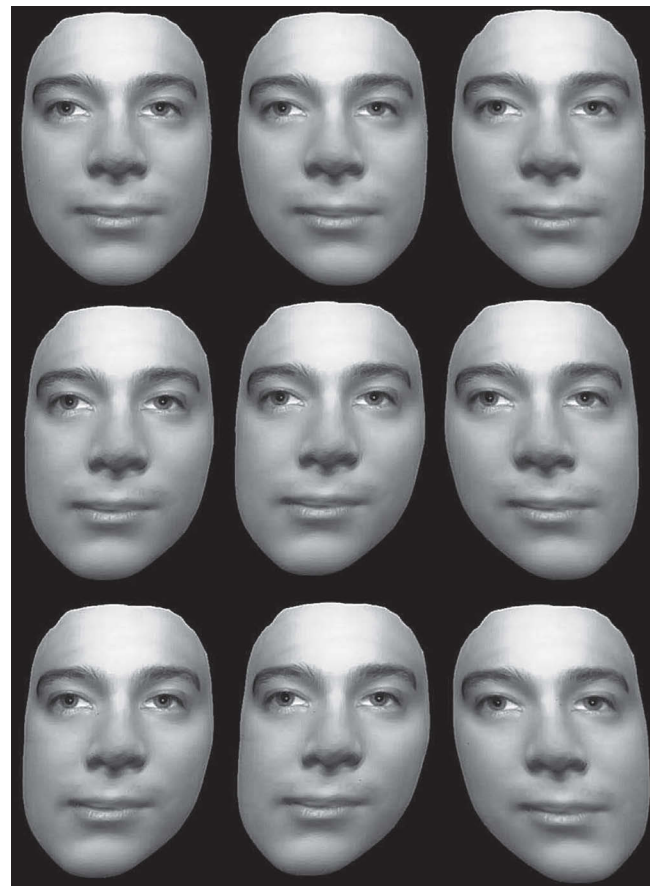


Figure 1 - Men with different levels of asymmetry (from the left upper side: 0 mm, 6 mm, 8 mm, 10 mm, 12 mm, 14 mm, 16 mm, 18 mm and 20 mm). Source: McAviney et al.¹, 2014.

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rubber bands and consequently reduces chair time and optimizes appointments. Importantly, other benefits have also been attributed to these devices; however, reduced treatment time remains as the focus of attention. Nevertheless, is this system really capable of reducing treatment time? With a view to answering this question, English researchers conducted a random controlled clinical trial² to compare the time spent for initial alignment and post-extraction space closure with conventional and self-ligating passive and active brackets. Their results reveal that the time spent for initial alignment was statistically less in the group with conventional brackets without differences between passive and active brackets. Regarding the time spent for post-extraction space closure, there were no differences between self-ligating active and passive brackets. These results are important and need to be widely divulged so as to avoid orthodontists to believe that treatment time might be reduced by changing the type of bracket, only.

VIRTUAL SETUP IN DIGITAL MODELS: A RELIABLE TOOL

The dream of foreseeing the future is shared by the overall population. Those who have the gift of doing so are seen as successful. In Orthodontics, the simplest and most trivial way of foreseeing the future of treatment is by manufacturing an orthodontic setup. Nevertheless, manufacturing a setup in dental casts is tiring and requires an eye for details so as to yield good final outcomes. An orthodontist hardly ever manufactures a setup for each one of his cases. However, digitization of orthodontic records, especially orthodontic casts, brings a new perspective to the concept of orthodontic setup. This new possibility does not require as much work and does not create as much mess as the conventional technique, given that it is produced based on images of virtual models. Nevertheless, some doubts are cast over virtual setups: Are they as reliable as conventional setups? With a view to answering this question, Korean researchers conducted a study³ to compare the results achieved by dental casts setups and virtual setups in digital models (Fig 2). Their results revealed that digital and conventional setups yield similar measurements for intra and inter-arch variables.

TOOTH PASTE WITH HIGH FLUORINE CONTENT REDUCES WHITE SPOTS IN ORTHODONTIC PATIENTS

White spot lesions underlying orthodontic appliances is a common complication found in orthodontic practice. The difficulty in performing proper hygiene is always justified by the presence of orthodontic appliances. Developing products that minimize such problems is a desire shared by the orthodontic community. Fluorine of various types and concentrations has been used by many years with this purpose. Tooth pastes with high fluorine content are available on the market and recommended for patients with difficulty in keeping proper oral hygiene. However, in this context, the following question arouses: Is this type of tooth paste really capable of minimizing white spots in orthodontic patients? With a view to confirming

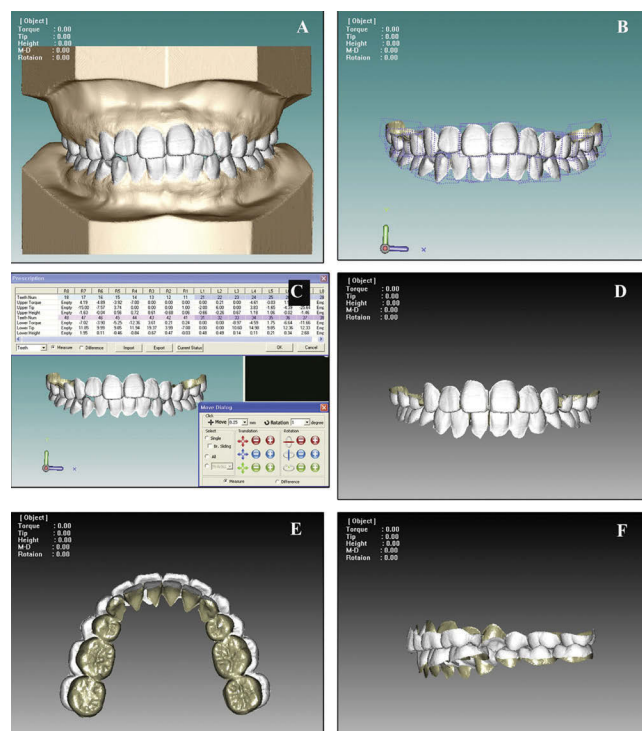


Figure 2 - 3D digital model and virtual setup procedures: **A)** 3D digital model; **B)** segmentation and normalization; **C)** checking tooth movement and changes in angulation and teeth proclination; **D)** virtual setup; **E)** assessing arch coordination and **F)** checking occlusal contact. (Source: Im et al.³, 2014).

such hypothesis, Swedish and Danish researchers conducted a random controlled clinical trial⁴ to assess the effectiveness of high fluorine content tooth pastes on orthodontic patients. Their results revealed that daily using high fluorine content tooth paste significantly reduces the prevalence and incidence of white spot lesions underlying fixed orthodontic appliances. The authors also highlight that this type of tooth paste must be considered as an alternative for patients with high risks of tooth cavity.

POSTERIOR CROSSBITE AFFECTS PATIENTS' QUALITY OF LIFE

Much attention has been given to the effects of oral problems, especially orthodontic issues, on patients' general health and well-being. Several oral problems might be associated with changes in patients' qual-

ity of life. An orthodontic problem shared by the overall population is posterior crossbite which might have a long-term effect on growth and development of teeth and maxillary bones, in addition to affecting mandibular movement and hindering temporomandibular joint dynamics. The aforementioned issue casts doubt on the following: Does crossbite affect orthodontic patients' quality of life? With a view to answering this question, Malay and English researchers conducted a study⁵ to assess the quality of life of 145 subjects of which 72 had posterior crossbite and 73 were in normal occlusion. Patients were aged between 15 and 25 years old. After applying quality of life questionnaires, the researchers came to the conclusion that posterior crossbite significantly affects patients' quality of life, thereby reinforcing the need for preventive and interceptive measures at an early age.

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The use of bisphosphonates does not contraindicate orthodontic and other types of treatment!

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Bisphosphonates have been increasingly used not only to treat bone diseases as well as conditions such as osteopenia and osteoporosis, but also in oncotherapy. The use of bisphosphonates induces clinicians to fear and care. These reactions are associated with controversy resulting from lack of in-depth knowledge on the mechanisms of action as well as lack of a more accurate assessment of side effects. Scientific and clinical knowledge disclosure greatly contributes to professionals' discernment and inner balance, especially orthodontists. Fear does not lead to awareness. For these reasons, we present an article that focuses on that matter. This article was adapted from different journals of different dental specialties, as mentioned on footnote. There is no scientific evidence demonstrating that bisphosphonates are directly involved with etiopathogenic mechanisms of osteonecrosis and jaw osteomyelitis. Their use is contraindicated and limited in cases of dental treatment involving bone tissue. Nevertheless, such fact is based on professional opinion, case reports, and personal experience or experiment trials with failing methods. Additional studies will always be necessary; however, in-depth knowledge on bone biology is of paramount importance to offer an opinion about the clinical use of bisphosphonates and their further implications. Based on bone biopathology, this article aims at contributing to lay the groundwork for this matter.

Keywords: Bisphosphonates. Osteomyelitis. Osteonecrosis. Orthodontics. Implants.

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Clinical practice must not be limited by fear which usually comes along with ignorance — whether licit, genuine or naive. On the contrary, we have to promote knowledge. Scientific wisdom must be based on scientific evidence rather than opinion, word or faith.^{2-5,10}

Personal and clinical experience is valuable when combined with scientific grounds and criteria. Similarly to personal and clinical experience, strictly laboratorial and/or experimental trials should not be considered in isolation either. Combining laboratorial, experimental and clinical outcomes with experience previously described in the literature allows well-grounded procedures to be established, thereby indicating true evolution.

As in any scientific research, results yielded by studies on bisphosphonates must be grounded on well-organized human samples comprising a proper number of subjects, given that there is a wide range of casuistries on human beings subjected to this type of treatment. Should research be conducted with animals, they must be in proper number and subjected to appropriate methods. A researcher, for instance, should not attempt to diagnose osteomyelitis and osteonecrosis in imaging exams of tiny rat mandibles. Diagnosis of bone disease requires a proper number of research animals and microscopic analyses performed by experts. In other words, one cannot reach accurate diagnosis based only on numerical measurements or counts of one or more than one bone component, whether structural or cellular.

Since the first bisphosphonates and bisphosphonate-related treatments (including treatment of osteopenia related to menopause conducted to avoid osteoporosis) arose, we have microscopically investigated its effects on maxillary bone, induced tooth movement, osseointegration and root resorption.^{7,8,11,13}

Although they have been widely used for medical purposes, bisphosphonates have caught dentists' attention in the last few years, only.^{9,11,13} Nevertheless, we notice great lack of basic scientific grounds that aid clinicians to understand not only bisphosphonates mechanism of action, but also their clinical applicability, side effects, variation in presentation and dosage. Ignorance leads to myths, controversies and mystification within any knowledge domain. And bisphosphonates are not different.

Some verbalized statements are disturbing, controversial and polemical, yet not well-grounded. For instance:

...patients taking bisphosphonates must not undergo dental treatment involving surgical procedures and bone biology, as it is the case of orthodontic treatment.

...patients taking bisphosphonates do not undergo bone remodeling because bisphosphonates "eliminate" clasts.

...patients taking bisphosphonates on a daily basis run a much higher risk of having jaw osteomyelitis.

Nevertheless, with a view to simply disagreeing with random arguments, we may ask ourselves:

- a) On which scientific evidence were these clinical decisions based? On which laboratory and clinical investigations published on which journals? Or were they based on case reports and clinical experience assessed by unskilled professionals who are unable to reach accurate, safe and systemic diagnosis of bone disease?
- b) How many patients take bisphosphonates on a daily basis and undergo dental treatment that includes oral rehabilitation with osseointegrated implants and orthodontic movement, and the clinician did not even hear about? Many patients do not report the use of bisphosphonates during the first interview or are advised not to report it so as to prevent their dentists from feeling scared.
- c) How many patients who take bisphosphonates actually have problems with rehabilitation and orthodontic treatment? And how many do not?
- d) What kinds of experience do people who make such statements have from a clinical, laboratory and pharmacological standpoint? On which scientific methods and diagnosis of metabolic, inflammatory bone diseases are they based?

With a view to enhancing understanding about the use of bisphosphonates in human beings as well as their clinical and therapeutic implications, we wrote this article. It addresses the use of bisphosphonates especially with regard to the specificities of Maxillary Orthodontics and Orthopedics.

Bone remodeling is the target phenomenon of bisphosphonates

Our 206 bones undergo continuous bone remodeling and have from one to three million points of

resorption with active BMUs, especially clasts. At these points, moments of bone resorption and neoformation alternate so as to cause skeletal renewal to occur within two to ten years, depending on body site, patient's age and other conditioning factors such as lifestyle and sex.

Should fracture occur in cases of osteopenia and consequent osteoporosis, active BMUs — especially clasts — undergo hyperactivity, acting directly on bone surface and removing mineral ions by releasing acids via active edge. While clasts demineralize, they degrade organic bone matrix by releasing proteolytic enzymes, especially collagenase. The by-product resulting from bone disassembly (ions, peptides, amino acids) is transposed to peripheral tissue by the clasts and through cytoplasmic vesicles that have their cellular membrane opened towards the opposite side of bone interface. This process of cytoplasmic transport of bone components in the clasts is known as transcytosis.

Bone remodeling does not involve the teeth, even though it occurs at approximately 250 micrometers from the cementum surface. On the root surface, cementoblasts do not have receptors for chemical mediators that promote bone remodeling or turnover such as those of systemic action, parathormone, calcitonin and estrogens; and local action, cytokines, growth factors and arachidonic acid products that act in bone areas associated with cellular stress and inflammation.²⁻⁵

Once mineral ions and other hard dental tissue components are incorporated, they cannot be naturally removed. Unlike bones, human teeth do not function as or account for a mineral or protein reservoir. Removal of permanent teeth components only occurs in cases of pathological conditions as a result of resorption. Osteopenia and osteoporosis, as well as endocrine system diseases, do not incur in impairment of root surfaces because they are protected by the cementoblast layer.

Bisphosphonates and their mechanisms of action

Since the 90s, bisphosphonates have been used as medication to control osteopenia and prevent human osteoporosis. They comprise a class of drugs that act on bone metabolism, especially due to its easy and quick combination/bonding with mineral

ions, particularly calcium. When ions such as calcium are incorporated into the bone matrix as a result of mineralization, they carry bisphosphonates molecules that become part of the structure naturally reabsorbed during natural skeletal remodeling.

During demineralization, the transport of bisphosphonate-bonded calcium via transcytosis carried out by means of clasts induce biochemical events capable of initiating apoptosis.²⁻⁵ This process of natural death — in which cells die by structure fragmentation without causing flow of enzymes or molecules that induce inflammation — minimizes bone resorption and slows down the process of remodeling. Thus, bisphosphonates contribute to control bone remodeling or accelerated bone turnover, thereby preventing osteopenia and consequent osteoporosis.

Other mechanisms of action acting simultaneously or parallel to those of bisphosphonates have already been studied and proved.^{2-5,7,8,10-14} The advent of bisphosphonates used to treat osteopenia and osteoporosis promoted an avalanche of publications, including extensive and thorough literature reviews. Every detail of this class of drugs has been properly explored on the book by Bijvoet et al.¹ In the following paragraphs, we present a synthesis of potential mechanisms of action of bisphosphonates.

The effects of bisphosphonates may occur in three different levels: in the tissue, cell or molecule. Bisphosphonates reduce the extent of absorption regions and the depth of eroded areas as a result of decreasing osteoclastic activity:

- a) They inhibit recruitment of cells towards bone surface.
- b) They inhibit cell activity.
- c) They reduce cell lifetime by inducing apoptosis.
- d) They affect the process of mineral exchange during bone resorption.

Some of the mechanisms of action that hinder bone resorption are considered controversial, given that they are incompatible with the type of bisphosphonate or bisphosphonate concentration. The effects produced by bisphosphonates include: decreased production of lactic acid, inhibition of some lysosomal enzymes, decreased synthesis of prostaglandins as well as decreased multiplication of macrophages.

There is evidence suggesting direct cytotoxic action over clasts. Action exerted over clasts could also result

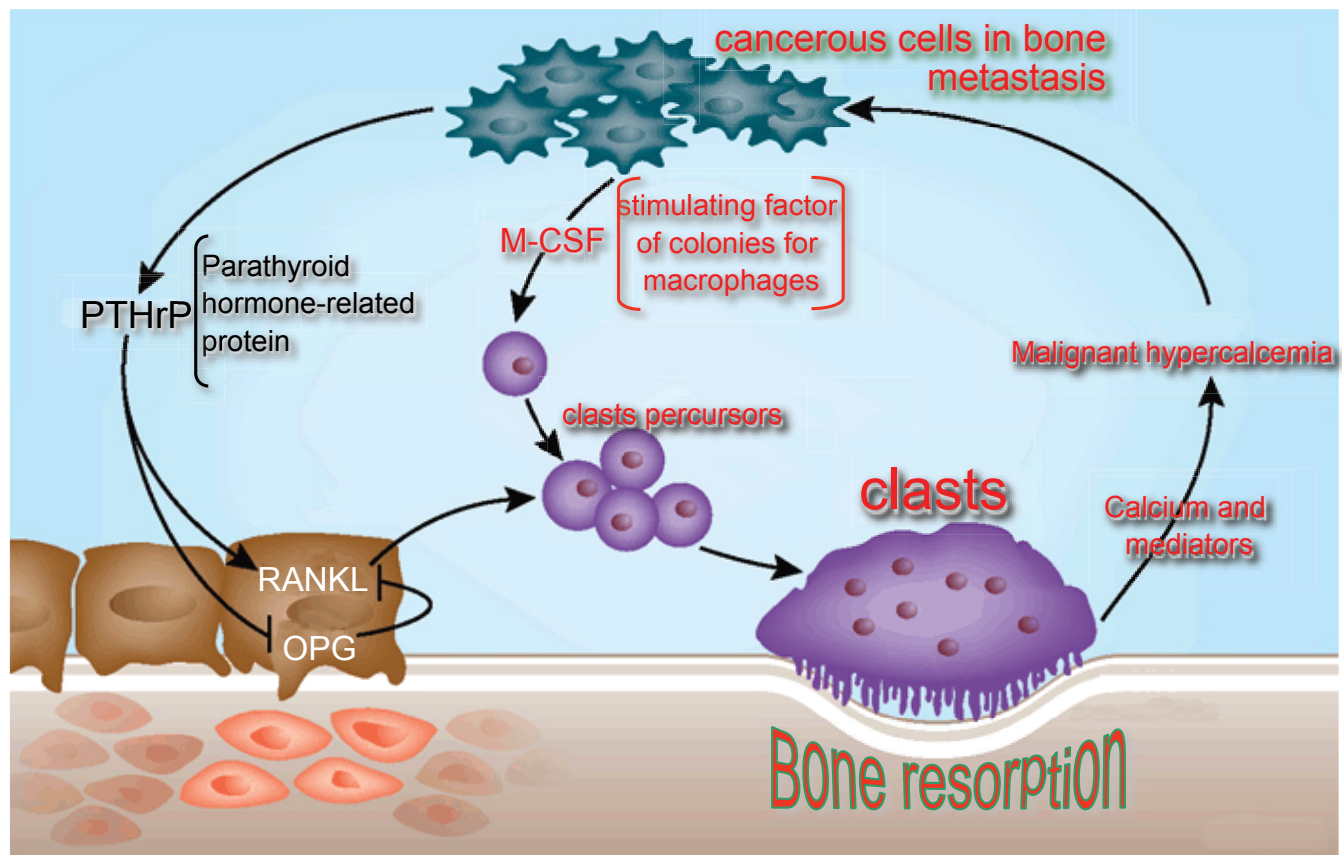


Figure 1. Neoplastic malignant cells release mediators that ease their dissemination in the skeleton. PTHrP is one of these mediators of which function is similar to parathormone, as it induces and stimulates resorption via RANKL so as to accommodate bone metastasis. At the same time, they release M-CSF, a mediator that stimulates the formation of clasts precursors and increases the number of neoplastic malignant cells. This process results in painful malignant hypercalcemia. Bisphosphonates aid to decrease clasts and control painful symptoms. (Source: Consolaro A³, 2012, adapted from Roodman GD. Bone-breaking cancer treatment. *Nature Med*, 13, 25-26, 2007.doi:10.1038/nm0107-25).

from their inhibition of adhering to bone surfaces. In addition to directly acting over clasts, bisphosphonates also inhibit bone resorption by the indirect action of osteoblasts which interfere in the function of clasts, given that these cells control the active BMUs and recruitment of clasts towards bone surfaces.

Several studies assert that bisphosphonates exert specific action over osteoblasts, particularly clodronate that — in relatively lower doses in comparison to bone resorption reduction or prevention — is able to affect differentiation of osteoblasts, thereby stimulating bone neoformation. Bisphosphonates promote secretion of osteoblasts that inhibit clasts formation and activity.

Bisphosphonates do not stop bone remodeling, they modulate it!

Bisphosphonates control uncontrolled bone remodeling. They act similarly to some pathological processes such as osteopenia and osteoporosis caused by lack of estrogen (typical of menopause). In these patients, controlled clasts formation and activity reestablishes balance in bone formation and resorption, both of which are essential for the maintenance of bones.

In other words, bisphosphonates aim at restoring bone physiology close to normality. Clinically speaking, bisphosphonates provide patients with comfort and quality of life. They are not anti-remodeling, they modulate and control the process instead.

Researches on induced tooth movement of animals and humans using bisphosphonates were conducted considering the type of bisphosphonates, dosage, administration route, experimental period and model of induced tooth movement. Neither of them assert nor reveal evidence that this type of drug contraindicates orthodontic treatment.^{2-8,10-14} There is no scientific support, methodologies, evidence or outcomes that allow such statement. The same is applied to the process of osseointegration.

Bisphosphonates and the risk of maxillary osteomyelitis during dental treatment: No biological or scientific evidence

In patients with malignant neoplasm, tumor cells release mediators that simulate the action and effect produced by parathormone on bone tissue. This occurs as a result of molecular similarities among mediators. Thus, patients with malignant neoplasm have extremely accelerated bone resorption and increased serum calcium levels, which is highly life-threatening. For this reason, this condition is known as malignant hypercalcemia.

Bisphosphonates can control uncontrolled bone resorption in oncological patients and, as a result, reduce or remove malignant hypercalcemia. One of the most important effects of bisphosphonates on malignant hypercalcemia is the elimination of intense painful symptoms, typical of this systemic condition.

Patients undergoing treatment of malignant neoplasm make use of several types of medication, including strong antibiotic, analgesic and anti-inflammatory drugs. They also make use of cytostatic and cytotoxic medication that act against malignant cells remaining at the lesion site as well as in other parts of the body, thereby killing them or hindering their proliferation.

Unfortunately, these medications produce antineoplastic side effects that decrease the production of leukocytes, the cells of our immune system. This happens because the bone marrow continuously produces these defense elements at an accelerated pace; however, when in contact with cytostatic and cytotoxic medications, it slows down and strongly impairs patient's immune system. Due to the same reason — low cellular proliferative capacity — regenerative repair processes are compromised.

Many patients undergoing oncological therapy also receive radiotherapy, especially at the primary source

of neoplasms; for instance, in case of maxillary neoplasm. During treatment, patients are not able to fully react against minor offending agents, especially microbial ones. Irradiated tissues have even lower capacity, especially maxillary bone tissues which are more susceptible to a particular type of osteomyelitis also known as osteoradionecrosis.

Nevertheless, many non-irradiated patients also often have osteomyelitis resulting from antineoplastic treatment, given that their mouth is more susceptible to receiving a large amount of different species of microorganisms.

Secondary osteomyelitis in patients with malignant neoplasm reflects a condition that has been acknowledged for decades; however, due to well-known frequency and etiology, has been trivialized and underreported in the literature.

Antineoplastic treatment protocols including the use bisphosphonates caught the attention of some clinicians who began to associate osteomyelitis with bisphosphonates side effects.

Used in isolation, bisphosphonates do not reveal any evidence of susceptibility to osteomyelitis. On the contrary, patient's impaired immune system and tissues with low reactional capacity, as well as the cytostatic and cytotoxic side effects of the drug, essential for antineoplastic therapy, do reveal evidence of susceptibility to osteomyelitis. In cases of normal patients, bisphosphonates have even lower chances of making individuals susceptible to mandibular or maxillary osteomyelitis. Bisphosphonates do not decrease the efficiency of patient's immune system as inflammation and immunologic response do. Furthermore, not only they do not decrease cell proliferation, but also are not cytotoxic for bone cells.

When does jaw osteomyelitis occur?

Jaw osteomyelitis occurs almost exclusively under two major clinical conditions:

- a) In patients with systemic disorders such as anemia, uncontrolled diabetes mellitus, leukemia, alcohol consumption, immunodepression, malignant neoplasm, among others;
- b) In patients with bone diseases and sclerosing jaw lesions; for instance, cases of Florid Cemento-Osseous Dysplasia and Paget disease.

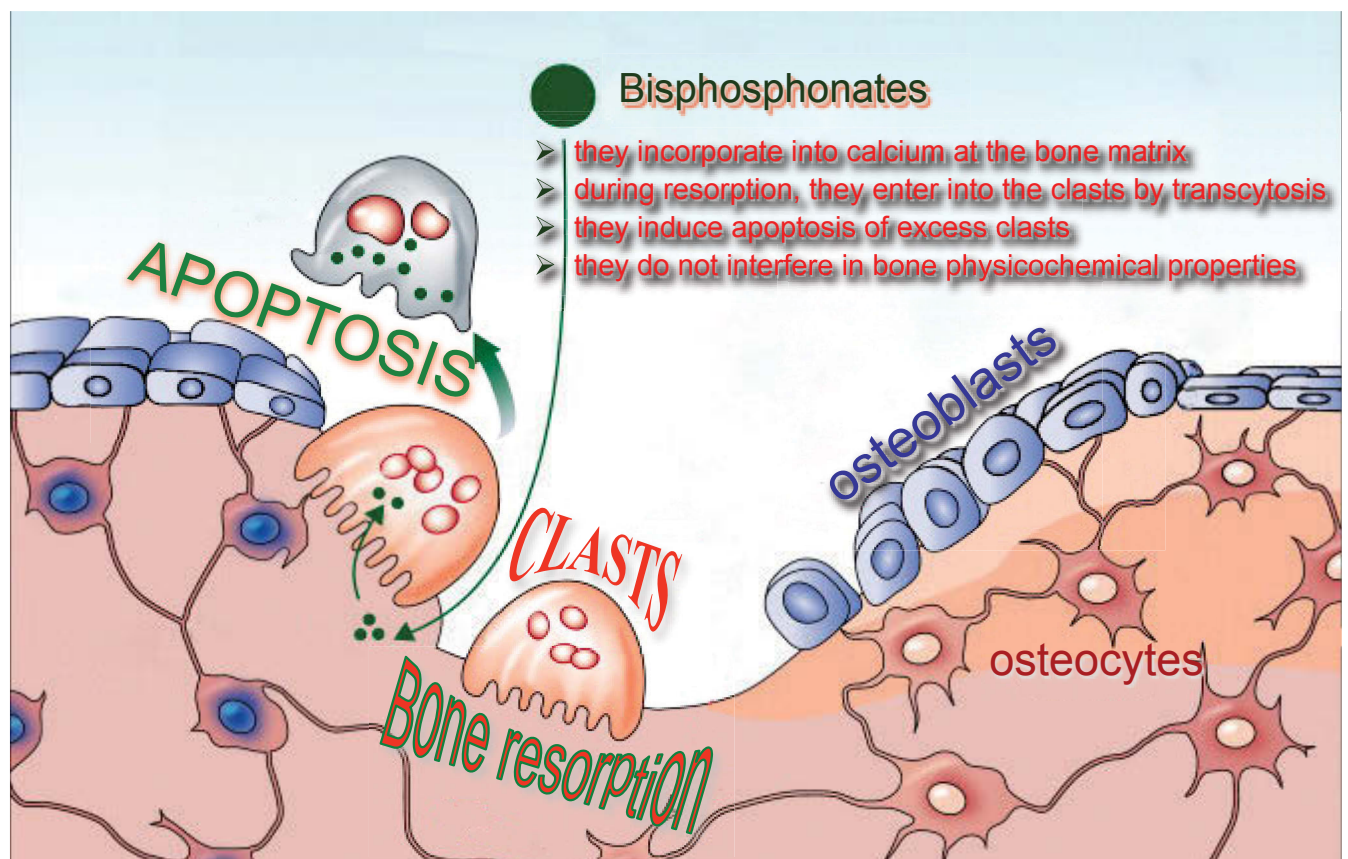


Figure 2. One of the mechanisms of action of bisphosphonates in controlling accelerated bone remodeling consists of controlling the number of clasts, thereby inducing apoptosis when it enters into the medication molecule during bone remodeling caused by transcytosis. Bisphosphonates are easily bonded to calcium and, as a result, incorporated by bone. (Source: Consolaro A³, 2012, adapted from Gennari e Bilezikian: Lancet, v.373, Issue 9671, 1225-1226, 2009 doi:10.1016/S0140-6736(09)60704-22).

Innumerable clinicians often seek professional advice on cases of patients using bisphosphonates to modulate bone remodeling of osteopenia and osteoporosis, especially because they “heard rumors” about the fact that these patients would be highly susceptible to osteomyelitis or that their teeth would never move again!

Questions most frequently asked by clinicians about patients using bisphosphonates are as follows:

- ... May I move patient's teeth?
- ... May I perform a periodontal surgery?
- ... May I move unerupted teeth by traction?
- ... May I perform implant placement?
- ... May I perform tooth extraction?

Even though the overall answer is yes, understanding the aforementioned questions is essential for the development of several researches on the influence of bisphosphonates over tooth movement, including clinical and experimental trials as previously suggested.

We have monitored several patients treated at different dental offices where periodontal, surgical, orthodontic and osseointegrated implant rehabilitation treatments are performed without further issues during or after therapy.

In order to reach accurate and complete diagnosis, every case of osteomyelitis must be questioned about the following: Which systemic disorder does the patient carry? The first interview and clinical examination must be supplemented by thorough, accurate complementary exams because systemically healthy patients do not usually have osteomyelitis!

Should healthy patients have osteomyelitis, it causes usually trigger localized bone inflammation restricted to the action site. In these cases, the condition is known as osteitis.

Osteitis may lead to neoformation of reactional bone, in addition to promoting resorption with focal radiolucent areas. We always have to bear in mind the following information.

a) Bisphosphonates are a class of drugs. For this reason, we must choose one and know which one will be used by each patient specifically, since each drug has its own pharmacological specificities. Bisphosphonates used to treat osteopenia and osteoporosis are not usually the same drugs used for oncological patients.

b) Bisphosphonates take longer to react with the organism. First, they need to be incorporated by the bone. Once they are absorbed, their molecules only act over clasts after bone remodeling affects the skeleton.

c) Jaw osteomyelitis requires systemic and local conditions that do not rely on the use of bisphosphonates. Systemically healthy patients scarcely have osteomyelitis. Healthy patients using bisphosphonates to control osteopenia and prevent osteoporosis must be considered healthy and normal from a dental standpoint.

When does osteonecrosis occur and how is it different from osteomyelitis?

Osteonecrosis conceptually accounts for *bone tissue and bone marrow death without infection caused by contact with microorganisms, in other words, in the absence of any microbial agent*. The causes of osteonecrosis of the human skeleton are:

- 1) Trauma, including bone fracture and surgery.
- 2) Autograft and allograft areas.
- 3) Internal and external radiation therapy applied to the affected area.
- 4) Use of corticosteroids.
- 5) Focal bone necrosis at different sites; for instance, in the femur head (Legg-Calvé-Perthes disease) and in the navicular bone (Kohler disease).
- 6) Organ transplantation, especially in patients with persistent hyperparathyroidism even after kidney transplantation.
- 7) Systemic diseases such as polycythemia, lupus erythematosus, Gaucher disease, sickle-cell disease and gout.
- 8) Osteochondritis dissecans of unknown etiology with fracture of articular cartilage and the underlying subchondral bone.
- 9) Emboli capable of leading to bone infarct and thrombosis caused by pressure exerted by local factors such as tumors.
- 10) Idiopathic factors similarly to what occurs with frequent osteonecrosis in the femur head of alcoholic patients.

Relevant medical literature does not usually comprise articles including bisphosphonates as a cause of osteonecrosis. In many cases, osteonecrosis will be inevitably considered as idiopathic, as it occurs in cases involving the femur head of alcoholic patients.

Osteonecrosis is cured differently in cortex and cancellous bones. Necrosed cancellous bone has its medullary portion gradually replaced by granulation tissue with pluripotent cells necessary for local bone remodeling. Necrotic bone trabeculae may be either reabsorbed by osteoclastic activity or involved by immature or primary bone produced by surrounding granulation tissue. By the end of the process, the trabeculae is remodeled and reshaped by a mechanism of intramembranous ossification.

In the necrotic cortical bone, vascular canals stimulate neovascularization of periosteum and endosteum and, as a result, lead to the formation of cones of bone resorption. Subsequently, the clasts open tunnel-shaped ways in the necrotic compact cortical bone, bringing osteoblasts along and, as a result, leading to bone neoformation. This process is slow and oftentimes deposits lamellar bone.

When does osteonecrosis change into osteomyelitis?

Pus formation does occur in cases of osteonecrosis in which osteocytes, osteoblasts and clasts of bone surface and medullary space lose vitality. Pus formation occurs as a result of interaction between bacteria and neutrophils. It requires the presence of bacteria, especially *streptococcus* and *staphylococcus*.

Osteonecrosis with pus formation necessarily implies in secondary contamination by pyogenic bacteria, given that osteonecrosis alone is not of microbial origin.

Should there be pus formation, the condition is known as osteomyelitis — even though osteonecrosis may be secondarily infected by bacteria, thereby causing osteomyelitis. Nevertheless, pus is not primarily part of its pathogenesis.

Alveolar bone density remains stable with the use of bisphosphonates

With a view to assessing alveolar bone density in organisms under action of alendronate bisphosphonates, Santamaria Jr¹³ histomorphometrically assessed

18 male *Wistar* rats equally divided into 1) Control group: without alendronate; 2) Experimental group: receiving 1 mgP/Kg alendronate since intrauterine life and for three months after birth.

Maxillary alveolar bone density was determined in cross section between the roots of murine molars. To this end, a crib with 1200 points was used to establish areas of bone tissue and marrow. Quantification was performed with the aid of Image J 1.34s software. Student's t-test was used to compare control and experimental groups. Significant differences were considered for $P \leq 0.05$.

Results revealed no statistically significant differences in alveolar bone density between animals using alendronate and the control group ($P = 0.3754$). Based on the methods employed, it is reasonable to conclude that bisphosphonate alendronate does not morphologically affect alveolar bone quality, thereby preserving the structural and mechanical tissue characteristics of healthy animals. It is worth noting that the alveolar region assessed herein is the site where teeth are experimentally moved. In other words, it is possible to say that ***orthodontic movement may be naturally planned in organisms under action of bisphosphonates.***

In his PhD dissertation, Santamaria Jr¹³ also reports a case of a 55-year-old patient who had been using bisphosphonate alendronate sodium for 10 years to treat osteopenia and osteoporosis. Later on, the patient was subjected to implant placement and orthodontic treatment with extraction, as well as paraendodontic and periodontal surgery without further complications or clinically observed changes attributed to the use of the medication. By the end of treatment, patient's esthetics and function were restored.

Requirements to discuss about bisphosphonates

In order to adopt and discuss about bisphosphonates, their indications, contraindications and consequences, a few requirements are necessary:

- » In-depth knowledge of bone biology, pathophysiology of clasts, osteoblasts, osteocyte and other structures involved in bone remodeling;
- » Extensive and in-depth knowledge of the pharmacological aspects of bisphosphonates so as to avoid the oversimplified belief of "I am against

or I am in favor" usually associated with opinion, faith and ideology characteristic of religion and politics.

Both statements are considered necessary not only to establish insights, but also to plan further clinical and research works on this subject that certainly requires additional investigation.

Final considerations

1) Bisphosphonates do not act to restrain, eliminate or deregulate bone remodeling, but to modulate, control and reestablish balance between bone resorption and neoformation. Should we consider the opposite extreme, cases in which the patient does not use bisphosphonates would be of major concern, given that bone remodeling could be affected.

2) Dentistry — especially Orthodontics and Maxillary Orthopedics — with its surgical treatment plannings, bone graft, dental implants and other bone biology-based procedures, must pursue treatment protocols that take advantage of the pharmacological benefits offered by bisphosphonates to bone remodeling and repair. Some of these advantages could truly benefit patients: Let's research and deepen our knowledge!

3) Bisphosphonates are pharmacologically different. Their use varies in accordance with indications.

4) The benefits offered by bisphosphonates do not allow generalizations based on specific cases which, most of times, are not deeply studied in clinical, imagiologic, microscopic and etiopathogenic terms.

5) Specific and isolated clinical cases are not capable of determining bisphosphonates contraindication or opinion. Without scientific basis, they may lead to wrong decisions and cause patients undergoing other medical therapies to refuse treatment with bisphosphonates.

Each case must be individually studied and planned without generalizations and with clinical decisions grounded on firm scientific evidence. Nearly all cases presented in the literature as having osteonecrosis and/or osteomyelitis associated with the use of bisphosphonates are not based on severe methodological analysis: There is lack of systemic previous assessment and bone morphology analysis prior to treatment, in addition to the presence of dogmatic assumptions.

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How sample size influences research outcomes

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Sample size calculation is part of the early stages of conducting an epidemiological, clinical or lab study. In preparing a scientific paper, there are ethical and methodological indications for its use. Two investigations conducted with the same methodology and achieving equivalent results, but different only in terms of sample size, may point the researcher in different directions when it comes to making clinical decisions. Therefore, ideally, samples should not be small and, contrary to what one might think, should not be excessive. The aim of this paper is to discuss in clinical language the main implications of the sample size when interpreting a study.

Keywords: Sample calculation. Sample size. Clinical trial. Methodology. Scientific evidence.

In recent years a growing concern has overwhelmed the scientific community in the healthcare area: Sample size calculation. Although at first blush it may seem like an overriding concern over methodological issues, notably to clinicians, such concern is utterly justifiable. This issue is of paramount importance.

Samples should not be either too big or too small since both have limitations that can compromise the conclusions drawn from the studies. Too small a sample may prevent the findings from being extrapolated, whereas too large a sample may amplify the detection of differences, emphasizing statistical differences that are not clinically relevant.¹ We will discuss in this article the major impacts of sample size on orthodontic studies.

FACTORS THAT AFFECT SAMPLE SIZE

The purpose of estimating the appropriate sample size is to produce studies capable of detecting clinically relevant differences. Bearing this point in mind, there are different formulas to calculate sample size.^{2,3} These formulas comprise several aspects which are listed below. Most sample size calculators available on the web have limited validity because they use a single formula — which is usually not divulged — to generate sample sizes for the studies.

The first aspect is the type of variable being studied. For example, it should be determined if the variable is categorical like the Angle classification (Class I, II or III), or continuous like the length of the dental arch (usually measured in millimeters).

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It is then necessary to determine the relationship between the groups that will be evaluated and the statistical analysis that will be employed. Are we going to evaluate groups that are independent, i.e., the measurements of one group do not influence the other? Are they dependent groups like the measurements taken before and after treatment? Are we going to use a split-mouth design, whereby treatment is performed on one quadrant and a different therapy on another quadrant? Will we be using t-test or chi-square test? All these questions lead to different sample size calculation formulas.

Subsequently, we have to answer the question concerning which results we envisage if a standard treatment is performed. What is the mean value or the expected ratio? The answer to this question is usually obtained from the literature or by means of pilot studies.

It is also important to determine what is the smallest magnitude of the effect and the extent to which it is clinically relevant. For example, how many degrees of difference in the ANB angle can be considered relevant? It is vital that we address this issue. The smaller the difference that we wish to identify, the greater the number of cases in a study. If researchers wish to detect a difference as small as 0.1° in an ANB angle, they will probably need thousands of patients in their study. If this value rises to 1° , the number of cases required falls drastically.

Finally, it is essential that the researcher determine the level of significance and the type II error, which is the probability of not rejecting the null hypothesis, although the hypothesis is actually false, which the study will accept as reasonable.

With this information in hand, we will apply the appropriate formula according to the study design in question, and determine the sample size. Today, this calculation is typically carried out with the aid of a computer program. For example, Pocock's formula² for continuous variables is frequently used in our specialty. It is used in studies where one wishes to examine the difference between data means with normal distribution and equal-size, independent groups.

PROBLEMS WITH VERY SMALL SAMPLES

Try to envision the following scenario. A researcher conducts a study on patients who are being treated with a new device which although very

uncomfortable has the potential to improve treatment of Class II malocclusions. The researcher wishes to compare the new functional device with the Herbst appliance. Patients will be randomly assigned to each group. The researcher is not aware, but we are, that s/he needs 60 subjects (30 patients in each group) to ensure sufficient power to be able to extrapolate the statistical analysis results to the overall population. In other words, so that we can feel confident that these results will serve as a parameter on which to base the proposed treatment. Furthermore, we also know, although the researcher does not, that this new therapy is less effective than the traditional method.

However, the researcher used only 15 patients in each group. The results of the study showed that the new device is inferior to conventional treatment. What are the implications?

The first is that using a sample smaller than the ideal increases the chance of assuming as true a false premise. Thus, chances are that the proposed device has no disadvantage compared to traditional therapy. Furthermore, it is assumed that people were subjected to a study, and had to undergo in vain all additional suffering associated with the therapy, given that the goals of the study were not achieved. In addition, financial and time resources were squandered since ultimately it will contribute absolutely nothing to improve clinical practice or quality of life. The situation becomes even worse if the research involves public funding: A total waste of taxpayer money.

PROBLEMS WITH VERY LARGE SAMPLES

There is a widespread belief that large samples are ideal for research or statistical analysis. However, this is not always true. Using the above example as a case study, very large samples that exceed the value estimated by sample size calculation present different hurdles.

The first is ethical. Should a study be performed with more patients than necessary? This means that more people than needed are exposed to the new therapy. Potentially, this implies increased hassle and risk. Obviously the problem is compounded if the new protocol is inferior to the traditional method: More patients are involved in a new, uncomfortable therapy that yields inferior results.

The second obstacle is that the use of a larger number of cases can also involve more financial and human resources than necessary to obtain the desired response.

In addition to these factors, there is another noteworthy issue that has to do with statistics. Statistical tests were developed to handle samples, not populations. When numerous cases are included in the statistics, analysis power is substantially increased. This implies an exaggerated tendency to reject null hypotheses with clinically negligible differences. What is insignificant becomes significant. Thus, a potential statistically significant difference in the ANB angle of 0.1° between the groups cited in the previous example would obviously produce no clinical difference in the effects of wearing an appliance.

When very large samples are available in a retrospective study, the researcher needs first to collect subsamples randomly, and only then perform the statistical test. If it is a prospective study, the researcher should collect only what is necessary, and include a few more individuals to compensate for subjects that leave the study.

CONCLUSIONS

In designing a study, sample size calculation is important for methodological and ethical reasons, as well as for reasons of human and financial resources. When reading an article, the reader should be on the alert to ascertain that the study they are reading was subjected to sample size calculation. In the absence of this calculation, the findings of the study should be interpreted with caution.

An appropriate sample renders the research more efficient: Data generated are reliable, resource investment is as limited as possible, while conforming to ethical principles. The use of sample size calculation directly influences research findings. Very small samples undermine the internal and external validity of a study. Very large samples tend to transform small differences into statistically significant differences — even when they are clinically insignificant. As a result, both researchers and clinicians are misguided, which may lead to failure in treatment decisions.

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An interview with

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Dr. Nigel Harradine qualified as a dental surgeon from Guys Hospital, London and also underwent undergraduate medical training, qualifying again from Guys. A medical house physician post followed at Guys and then a year as an intern in London, Ontario before he settled on orthodontics as his chosen specialty and returned to the United Kingdom. A year of full-time general dental practice was followed by the two-year orthodontic course at the Royal Dental Hospital, London and Kingston Hospital, Surrey where he studied under Prof. Bill Houston and Harry Orton the Consultant orthodontist. In 1981, Dr. Nigel went to the Eastman Dental Hospital, initially as a lecturer and then as a senior lecturer in orthodontics. Since 1984 he has been a consultant at Bristol Dental Hospital and School where he is in charge of the undergraduate program and fully involved in the postgraduate teaching. Dr. Nigel has published innumerable papers, related to self-ligating brackets, TADs, orthognathic surgery, functional appliances, including a random prospective trial of the effects of third molar extraction on later incisor crowding. He has also contributed invited chapters to a number of textbooks. With David Birnie, Nigel Harradine has co-presented the annual Excellence in Orthodontics Course since 1987 and has lectured extensively throughout the United Kingdom including multiple presentations to the British Orthodontic Conference and the Consultant Orthodontists Group Symposium, including the Chapman Lecture, the Ballard Memorial Lecture, the Northcroft Lecture and the Webb Johnson Lecture. In total, Nigel has given 390 external invited presentations on the UK. In addition to Excellence in Orthodontics courses overseas, Nigel has delivered invited lectures and courses in Australia, France, Germany, Israel, Mexico, Malaysia, New Zealand, Norway, Serbia, South Africa, Switzerland, The Netherlands and the USA, where he has given six presentations to the Annual Session of the AAO, a two day course at Chapel Hill and keynote presentations to the Pacific Coast Society and in 2010 to the College of Diplomates of the American Board of Orthodontics – a total of 170 presentations. Away from the chairside and the podium, Nigel's roles have included being the President of the British Dental Association hospitals group, Chairman of the British Orthodontic Society scholarship committee, Chairman of the English Royal College working party on Read Coding, Secretary for seven years of the Royal College Orthodontic Audit working party, Secretary of the British Orthodontic Conference Organizing Committee, Chairman of the British Orthodontic Society Computer Users Group and a member of the British Orthodontic Society Council. He is a past Chairman of the Consultant Orthodontists Group of the BOS and a previous Clinical Director of Bristol Dental Hospital. Nigel was the initiator and inaugural chairman of the British Orthodontic Society Foundation which supports research and teaching in Orthodontics. Dr. Nigel kindly agreed to granted this interview to Dental Press Journal, and very interesting questions were formulated by Dr. Ricardo Moresca, Weber Ursi and Jonh Pobanz and myself. The main issue was SLB systems and we hope you can enjoy the wonderful experience and knowledge from Dr. Nigel Harradine.

Mauricio Accorsi

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It is undisputed that self-ligating brackets have been massively advertised by their manufacturers in marketing campaigns, targeting the end consumer. How do you evaluate the relationship between science and economic interests? The marketing can be considered one of the problems that self-ligating brackets faces for its popularity? Ricardo Moresca

I agree that some of a number of the claims made on behalf of self-ligation are in my view counter-productive in terms of encouraging their adoption. I think there are certainly worthwhile advantages in the use of self-ligation, some of which are definite and established and some of which remain untested at this stage. However, some of the less likely claims made on their behalf diminish the credibility of the advantages that are there to be had.

However, to put this in perspective, I don't think that developers of any bracket or other orthodontic equipment can be too heavily criticized for putting forward some over-optimistic claims for their baby. Without this enthusiasm, many of our most valuable tools would not have been developed. In particular, manufacturers are reluctant to invest heavily in a new bracket and then see the development through to a good, reliable, practical product without the prospect that it might be a game-changer. Self-ligating brackets (SLBs) are not alone in this respect. Many developers of some excellent and highly useful functional appliances believe strongly that their appliance grows mandibles to a substantial degree, although the evidence does not support this. Self-ligating brackets have attracted particular attention and criticism for some over-enthusiastic claims partly because they have been so successful in sales terms. Incidentally, the sales success does indicate that many orthodontists do find that these brackets have advantages.

It is well known currently from clinically and scientific evidence, that we may have difficulties in rotational control when the self-ligating systems are used. One solution that has been presented to overcome this problem is to use two wires simultaneously (0.014-in and 0.016-in on a 0.022-in system, for example) in order to fulfill the bracket slot and eliminate this deficiency. What is your opinion about this approach?

Ricardo Moresca

I don't think there is good scientific evidence that rotational control is different with SLBs. This has not been investigated much and often only incidentally. The many studies of alignment capability have found that this is very similar for SLBs and conventionally-ligated brackets. In a recent split-mouth study¹ of canine retraction on 0.018" stainless steel wires, self-ligating brackets were found to give better rotational control of the canine than conventionally ligated brackets. SLBs are also not liable to the well-documented effects of elastomeric decay which can cause loss of tooth control.

Not all SLBs are equally effective. The only bracket for which the use of twin wires is advocated is the Smartclip bracket. The reason for that advocacy is not related to rotational control. The reason is that the Smartclip bracket is the only SLB where you do not open the clip or slide to insert or remove the wire; you have to push and pull the wire through the closed spring mechanism. This causes an inherent conflict of design. If the spring clip is sufficiently soft that the wire can be removed easily and without causing pain, then it tends to permit spontaneous loss of ligation. Early Smartclip brackets had a springclip which was too stiff. Engagement and removal of thicker wires was very uncomfortable. This was documented in a random controlled trial (RCT)² as well as being a widespread clinical finding. So they redesigned and softened the clip, but there is a limit to how much you can do this. So several clinicians advocated using two thin wires rather than one thicker (eg 0.014 x 0.025-in or 0.016 x 0.025-in NiTi) wire to try to get round this dilemma and give comfort plus better control. They also advocate restricting the use of stainless steel wires as much as possible for the same reason. This is a sensible if inconvenient and somewhat restricting policy to get round the limitations of that particular design which no other manufacturer of the more than 30 types of available SLBs has adopted. A good clinician can often get round inherent limitations of a bracket or archwire (as we do with conventional brackets) but that does not make it the most sensible way to go.

Some clinicians feel that they have more trouble getting maximum alignment with SLBs and this may be a fact for them although the RCTs have not so far shown any difference. There is no reason arising from the bracket itself why this should be the case but I suspect the following are the potential reasons for some people finding this. Firstly, the brackets are unfamiliar in shape and whenever

clinicians swap to a different make of bracket they find it harder to position as well as the brackets they are used to. Secondly, many SLBs are slightly narrower brackets in order to keep forces lighter and this may increase the need for accurate placement. Lastly, because the archwire has to be fully engaged with a SLB, any imperfections in bracket placement may be more fully expressed than if the elastomeric permits an incomplete engagement right to the end of treatment. Many clinicians including myself find no problems in getting the teeth very aligned with SLBs and in fact it is the cases which I treat with conventional ligation in which I sometimes have to regain control of one or more teeth.

In 2008, I attended your conference at the AAO Congress in Denver. That occasion you asserted that there was still no evidence that self-ligating brackets afforded faster treatments, but this could change in the future. After almost six years and after a lot of research, what is your current opinion over this topic? Ricardo Moresca

There is still no evidence from RCTs that SLBs result in faster treatment although some controlled case series have shown this. The logical deduction is that SLBs do not offer a large inherent advantage in this respect. However, all RCTs to date have used SLBs as though they conventional brackets. They have used the same archwires, same appointment intervals and same biomechanics as with their conventionally ligated brackets. This is an understandable first approach and it has the advantage that the only difference between the two groups is the bracket so any difference can be attributed to the bracket. However, my view would be that there is very extensive research to show that SLBs give a very different proportion of applied force to the movements you want and they swallow up much less in the resistance to those desired movements and this difference should be exploited in the treatment mechanics to get the best from the brackets.

E.g. with thick wires:

Good studies by Thorstenson and Kusy^{3,4,5} have investigated aspects of this topic. They examined the effects of varying active tip (angulation) on the resistance to sliding (RS). They found that angulation beyond the angle at which the archwire first contacts the diagonally opposite corners of the bracket slot causes a similar rise in resistance to sliding of both self-ligated (Damon SL) and

conventional brackets. However, at all degrees of tip, the Damon brackets produced significantly less resistance to sliding. At an angulation of 6 degrees, which they chose to be clinically realistic for an 0.018 x 0.025-in stainless steel wire in an 0.022" slot, the difference is 60 gm per bracket which is very probably of clinical significance. Their second paper⁴ compared different self-ligating brackets for resistance to sliding with active angulations. It quantifies a little more closely the lower resistance to sliding with passive self-ligation and points out that low resistance to tooth movement can lead to unanticipated movement. The third paper⁵ examined the same factors with wires of different sizes and in the dry state. The increase in friction when larger wires deflect the clips in active self-ligating brackets is quantified and the scanning electron micrographs of the different brackets show very clearly the relationship between small and large wires and active clips and passive slides. A study by Matarese⁶ is yet another to show that irregularity of the teeth does not prevent self-ligating brackets (Damon 2 in this instance) from producing significantly less resistance to sliding.

The views expressed on this important point vary widely, even when the same research is being quoted. For example, Brauchli et al⁷ quote data from Thorstenson and Kusy³ to the effect that for an 0.018 x 0.025-in wire, "with angulations of 7° between the archwire and slot, more than 94% of the RS is caused by binding". This has been taken to imply that the contribution to RS from the lowered friction with self-ligation is irrelevant whenever archwire activation causes binding. In fact, it is of course the very low friction with self-ligating brackets that makes any binding component such a high percentage of the overall RS. If the friction is zero, the binding component will constitute 100% of the RS. The other way of accurately describing the same data is as I have done in the preceding paragraph – "At a realistic angulation of 6 degrees for an 0.018 x 0.025-in stainless steel

Angulation (degrees)	Damon SL	Conventional bracket
0	0	34
3.5	0	55
6.0	80	140

Resistance to sliding (RS) for different bracket angulations with a 0.018 x 0.025-in archwire. Forces in cN. The difference is 60 gm at 6 degrees of angulation (Source: Thorstenson & Kusy³, 2001).

wire, the difference is 60 gm per bracket which is very probably of clinical significance". Pliska et al⁸ have also investigated the relationship between tipping moments and RS. They too found that at high levels of tip, any reduction in friction is drowned by the high binding, but at lower, more clinically realistic levels of activation, a potentially significant reduction in RS was seen as expressed in grams for force. In their words, "At the higher moment levels (4000 g-mm), no significant reduction in RS was found between conventional (CL) and self-ligating (SL) brackets on both SS and NT archwires. At lower levels of applied moment (2000 g-mm), reductions in RS of 18% (42.7g) and 18% (38.5 g) were found between the CL bracket and the best performing SL bracket on NT and SS, respectively."

Studies of net aligning force – thin aligning wires:

The aligning force remaining after the RS is deducted is the other side of the resistance-to-sliding coin and is an equally important way of exploring and expressing RS. Until recently this has been inadequately appreciated and investigated. Almost all studies had measured the force resisting an archwire sliding along a wire. Three recent and excellent papers have explored this the converse — namely the net aligning force remaining in an archwire in spite of the resistance to sliding — when a tooth is significantly misaligned. Baccetti et al⁹ measured this in relation to vertical displacement of a tooth. The rather novel and well-considered difference from many studies is that their Instron machine did not measure the force required to pull an archwire through the brackets, but measured the residual net aligning force on the misplaced tooth. They found that at low levels of misalignment there was little difference between ligation methods, but beyond a 3 mm vertical misalignment, with conventional ligation the aligning force available was very substantially reduced by conventional ligation. At 6 mm displacement there was no remaining aligning force with conventional ligation but 40 to 120 gm remaining for self-ligating brackets. A current study by another research group of alignment of irregular teeth Nucera et al¹⁰ have also found the same redistribution of applied forces when self-ligation is used. "The NT wires released significantly lower forces with conventional ligation" and "clinicians should couple SLB systems with an alignment wire that exerts lighter forces".

So, if you have much less resistance to sliding and more force left over to do what you want and you

combine this with a ligation that won't permit the tooth to rotate off the wire then you can – and should – break some of the conventional 'rules'. You should treat the cases more like Begg cases. You apply lighter forces (because less force is lost through RS) and you start applying all the intra- and inter-arch mechanics (eg class II traction) that you normally delay until later because we are taught to avoid the adverse effects of applying such forces to light wires. But if the forces are lighter and there is less obstruction to movement and you can pull on a canine tooth for example without the ligation allowing undue rotation, then you can get much more done earlier in the treatment. So the RCT that needs doing is to test two groups with the different ligation, but both groups treated with mechanics adapted to take advantage of SLBs. Then we will know about efficiency of treatment.

Together with Dr. Birnie, you hold a course called "Excellence in Orthodontics" every year in the UK. Please explain what the course covers and what level of participants attend such courses. Weber Ursi

Yes, indeed, this year was our 28th annual London course and we also give the course overseas on request. This year we are giving it in Sarawak as part of the Asian Pacific Conference in October. The course is open to anybody who is keen to learn, although almost everyone is a specialist orthodontist or an orthodontic trainee. A significant number of people come every few years to update. I attach this years London timetable and you will see that we cover a wide range of topics which vary each year depending on what we feel is most relevant in terms of the latest evidence or developments in technique. The course combines a critical look at the literature with lots of clinical examples. For more information, have a look at the EinO website at <http://www.excellenceinorthodontics.com>

How does your medical training influence the way you treat your Orthodontic patients?

Weber Ursi

Interesting question. I think it happens to give me a broader perspective on the place of orthodontics in the overall provision of healthcare and its contribution to quality of life. You don't need to have trained and worked as a medical doctor to have that but it help and

that area of research is becoming much more important to defend the role of orthodontics in healthcare as opposed to a beauty treatment such as hairdressing or botox therapy.

What is your preference regarding self-ligating brackets, passive or active? What is your opinion of using active SLB in the anterior teeth for better torque control and passive SLB in the posterior teeth for less friction? Weber Ursi

I have written in detail about this in a number of papers and book chapters but in summary, I think the active vs passive question is much less important than other aspects of bracket design such as how easily they open and close, how robust the self-ligating mechanism is, how secure against inadvertent opening it is, whether the mechanism is susceptible to calculus formation, whether it gets in the way of placing elastomeric chain or wire underties, whether the mechanism loses performance during treatment (one well-known bracket has been shown to suffer from this¹¹) and similar considerations.

» Friction: Friction is higher with most active SLBs than with most passive SLBs but my feeling would be that those differences are of less clinical significance than the factors I have mentioned above.

» Torque: There is sound evidence from a number of papers that the labial force from an active spring clip supplies a clinically insignificant contribution to torqueing force. Brauchli et al^{7,12} are probably as good papers as any on this.

So I don't think that any differences in relation to torque control or friction are likely to be large enough to justify using both in the same arch. I have used 15 types of SLB and I still treat some case with the postgrads with conventional ligation and I find no differences in torqueing control. The only proviso is that you must make sure the archwire is fully engaged behind the face of the slot for the torque force to be as it should for that size wire. With a passive SLB (or a molar tube), the wire has to be fully engaged or you cannot get the slide to close or the wire into the molar tube. With a wire or elastomeric ligature it is possible to get the rectangular wire incompletely into the slot and still send the patient away with all the teeth 'ligated'. As it happens, I am speaking about this topic this week at the AAO in New Orleans.

Why do you think existing passive self ligation systems lack rotation and torque control during finishing? John Pobanz

I don't – see above. If someone thinks that a ligature would provide rotation or torque control, then why not add a ligature to the SLB? This can easily be done with almost all SLBs. I think they would be disappointed with the additional effect of the ligature and this indicates that the ligation is not the problem.

What is your protocol for posterior crossbite correction? John Pobanz

I usually find that cross elastics from the first visit with the bite propped open work well. I may prop the bite posteriorly with reinforced glass ionomer on the lower molars or anteriorly with bite turbos if the overbite needs reducing. People tend to wear elastics well at the start of treatment and the teeth tip quickly over the bite because the light round wires permit that. Once the teeth are not in crossbite, the occlusion helps upright the tipped teeth and thicker wire do the rest. If the crossbite is unusually severe and generalized, I sometimes use a quad helix. The nuisance of that is that you have to separate, fit bands, send it to the lab or adjust a pre-formed quad in the mouth and of course you cannot easily align the molars well until you remove the quad, so it has to be worth the extra hassle. All the literature supports the view that in the long term the difference in bodily / orthopedic change is small with archwires vs quads vs RME. A current study¹³ compares expansion with a quad helix and conventional ligation with archwire expansion using Damon 3MX brackets. The expansion achieved was the same in both groups (approximately 5 mm at the premolars and 3.5 mm at the molars) with slightly more buccal tipping in the Damon group. This can be interpreted as suggesting that:

» Quad helix appliances add little to the treatment.

» There is no "Frankel-like" effect of Damon brackets and buccal soft tissues.

This paper also quotes other research finding similar buccal tipping of the teeth with Damon and with RME so you can pursue that aspect via this current paper. I personally have not used RME for years. The CT research by Garib et al¹⁴ has demonstrated very large

dehiscences of buccal bone following rapid maxillary expansion, so if you use RME it should be done cautiously and in young patients.

One other trick which works well as an alternative to a quad is to place an additional expanded thick wire in the headgear tubes at the start of treatment and ligate it to the main archwire at the front of the mouth to keep it in place and in control. This assumes that you have headgear tubes on your molars – which I usually don't.

Do you see any merit to stainless steel mini-screws compared to titanium mini-screws?

John Pobanz

No. Titanium is more biocompatible and will osseointegrate more but whether this makes any difference in miniscrew usage, I wonder.

Orthodontics as specialty, seems to experiencing a paradigm shift without precedents, and SLBs are playing an important role in this context, along with 3D imaging (CAD/CAM Systems), TADs, Genetic Engineering, Bioengineering, Integrative Medicine, Minimally Invasive Dentistry and so on. All together to achieve better, predictable, safer and faster results. So, do you believe that "this is really the future"? in other words, do you believe that the contemporary Orthodontist has to relearn everything again?

Mauricio Accorsi

I certainly think that the rate of development of knowledge and of new technologies is currently rapid and that we do really have to keep up with the advances in both of those areas. Firstly, these developments are improving our ability to consistently deliver good results with a better patient experience. For example I think that intraoral scanners have at last become good enough to be widely adopted. I think that in a few years alginate impressions will be a small part of our record collection and appliance manufacture. I think that CAD/CAM design of individually customized appliances will become much more widely used and that treatment will be shown to be better and quicker. Some of the less invasive technologies which are currently advocated for speeding up tooth movement may prove to be effective, which would also enhance the patient experience. The other effect of new technology in orthodontics is that the scope of diagnosis and treat-

ment will probably widen. We have already seen this with the introduction of TADs. Malocclusions such as some anterior open bites and some class III can now be treated using TADs that previously required orthognathic surgery. This is an exciting and significant advance. Cone beam CT scanning expands our ability to ethically investigate the effects of orthodontics on airway dimension and our role in treating sleep apnoea. This is potentially important for a speciality which is liable to criticism that it is purely cosmetic with little health benefit. Orthodontic research tools are also important in that context, with the development of better ways of measuring the oral-facial quality of life now starting to demonstrate the wider effects of orthodontics on all-round well-being.

This does not mean that we have to unlearn anything we have learnt but it does mean that we have to progressively change our practice if we are to do what is best for our patients. This is not comfortable for many people. We get to be very good with the ideas we have and very skilful with the clinical tricks that we know and faced with a busy clinic we tend to stick with what we know we can do without the day being stressful. We go away from a conference and think that we have heard some very interesting things, but the urge to change our practice may get put on the back burner in the interests of not having the stress of being a beginner with something new. However we are always building on previous skill and ability to relate well to patients and to understand the underlying mechanisms of tooth movement and appliance design. That is a strength and change is interesting, stimulating and rewarding and should keep us enthusiastic and engaged.

Reducing the number of extractions during orthodontic treatment has been one of the supposed advantages attributed to SLBs treatments. Do you think this can be true and, based on which factors do you make your extractions decision?

Mauricio Accorsi

To summarize on that question, I think that self-ligation probably makes it easier to squeeze teeth into line if they are substantially irregular and crowded. We don't yet know for certain if they are indeed more efficient at doing that, because no RCT has yet focused on substantially crowded cases, but the laboratory evidence gives reason to propose that this may be the case and you will have seen some impressive individual cases. So if

you wish to extract less in such cases, self-ligation may make that easier to achieve. However, that does not of itself mean that you should change your treatment goal in terms of arch width or incisor labio-lingual position. I personally do not believe that the way you align teeth alters the factors that determine where they will be stable or where they will look nice or where they will enable a good occlusion. We need to distinguish the means of aligning the teeth from the goals we have for their final position. There have also been some well-known hypotheses that the lower forces needed to move teeth with SLBs may enable the lips to more effectively resist labial movement of the incisors – the “lip bumper effect”. I remain in need of convincing about that suggestion. If it does apply, I suspect it is only in those cases where the lips are tight and strong and the clinician is careful to keep the forces low that this effect might apply. So far, no studies have supported this effect, but to date, the most likely sample of patients and the best use of the demonstrated biomechanical differences of SLBs have not been used in a RCT. There has also been the proposal that tongue posture may be altered when the lip forces are able to interact with the forces we apply. I remain sceptical about that idea too, although it is difficult to test. Cases treated with SLBs which show less incisor proclination and more uprighting of buccal teeth than we might expect probably contain lessons for us about planning and treatment but not necessarily that we are altering tongue behavior or permitting the lips to compete with orthodontic forces.

With advances in appliances, extractions have become less necessary for us to achieve a good set of study models and that is good and useful and helps us to remove and throw away fewer healthy teeth, but the final position of that occlusion in relation to the face and the supporting tissues continues to be determined by our understanding and continually developing knowledge of aesthetics, occlusion and periodontal health.

You may be familiarized with Dr. Chris Chang's approach for Class III and gummy smile treatments by means of OBS (OrthoBoneScrews). What is your opinion about this philosophy?
 Mauricio Accorsi

Yes I am familiar with Chris Chang's approach to this (and to his very entertaining lecturing style). I have not tried his exact recipe but I have used Hugo de Clerck's miniplates for a number of young class 3 patients with some good success and some teething problems with getting the surgery done just 100% right. I have also used anterior midline miniscrews to intrude upper incisors. I think that this area of biomechanics offers a very exciting period of development in orthodontics. As with all new techniques, they are not as universally successful or without problems and a necessary learning curve as the enthusiastic promoters tend to suggest, but the benefits are definite and the scope of orthodontics is definitely increased.

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Influence of initial occlusal severity on time and efficiency of Class I malocclusion treatment carried out with and without premolar extractions

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Introduction: The aim of this retrospective study was to compare the occlusal outcomes, duration and efficiency of Class I malocclusion treatment carried out with and without premolar extractions in patients with different degrees of initial malocclusion severity.

Methods: Complete records of 111 patients were obtained and divided into two groups: Group 1 consisted of 65 patients at an initial mean age of 13.82 years old treated with four premolar extractions; whereas Group 2 consisted of 46 patients at an initial mean age of 14.01 years old treated without extractions. Two subgroups were obtained from each group (1A, 1B, 2A and 2B) with different degrees of malocclusion severity according to the initial values of PAR index. Compatibility was assessed using chi-square and t-tests. The subgroups were compared by means of Analysis of Variance (ANOVA). The variables that might be related to treatment duration and efficiency were assessed using the multiple linear regression analysis.

Results: Initial malocclusion severity was positively related to the amount of occlusal correction and consequently to a higher efficiency index. Moreover, extraction protocol showed a positive relationship with treatment duration and a negative relationship with treatment efficiency.

Conclusion: Extraction and non-extraction protocols for correction of Class I malocclusion provide similar satisfactory results; however, the extraction protocol increases the overall treatment duration. Orthodontic treatment is more efficient in cases with high initial malocclusion severity treated with a non-extraction protocol.

Keywords: Class I malocclusion. Efficiency. Time. Tooth extraction.

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INTRODUCTION

Assessing treatment outcomes by means of occlusal indexes allows us to understand the effects different types of appliances, techniques and treatment protocols produce on dental occlusion,^{1,4,8,13,20,28,33} treatment time^{2,3,10,21,34} and efficiency. In this context, efficiency is described as the achievement of the best results within a shorter period of time.^{19,31}

Some authors have observed the influence of dental extractions on correction of initial malocclusion severity, showing better occlusal results when a non-extraction protocol was used.⁶ However, they observed that in Class II malocclusion cases, the protocol that included the extraction of two maxillary premolars yielded better occlusal outcomes than the non-extraction and the four-premolar extraction protocols.^{19,20}

Regarding treatment time, the literature generally highlights dental extractions as one of the main factors for increased treatment time.^{6,10,34} Contrary to those findings, Beckwith et al³ stated that the difference in treatment time between extraction and non-extraction protocols is not significant. Other authors also assessed the influence of malocclusion severity on treatment time and found no relation between treatment duration and initial malocclusion severity.¹⁶ Nevertheless, other studies have shown that there is a direct correlation between initial malocclusion severity and the treatment duration.^{6,10}

Unfortunately, these previous studies used mixed samples that included different types of malocclusions and treatment protocols. Therefore, the applicability of their findings is limited and cannot be extrapolated to Class I malocclusion.

The objective of this study was to compare the occlusal outcomes, treatment duration and efficiency of two different protocols for Class I malocclusion: non-extraction and four-premolar extractions, in order to elucidate the effects of dental extractions on orthodontic treatment performed for this specific malocclusion.

MATERIAL AND METHODS

Material

The sample of this retrospective study comprised patients with Class I malocclusion and similar pre-treatment characteristics who were treated with four premolars extractions or without extractions. Patients were selected from the Master's and Postgraduate

Orthodontic programs at the School of Dentistry of University of São Paulo, Bauru, Brazil. In selecting the sample, the following inclusion criteria were applied:

- » Class I malocclusion treated without extractions or with extraction of four premolars, two maxillary and two mandibular.
- » Presence of all permanent teeth up to the first molar.
- » Presence of crowding not greater than 8 mm.
- » Absence of supernumerary teeth.
- » Absence of impacted teeth.
- » Absence of abnormalities in tooth size and / or shape.
- » Treatment with full fixed Edgewise appliances.
- » No history of orthognathic surgery.
- » Full orthodontic records available for review.

The sample comprised the initial and final orthodontic records of 111 patients who were divided into two groups according to the extraction protocol used as part of the orthodontic treatment.

Group 1 consisted of 65 patients, 24 males (36.92%) and 41 females (63.08%), with initial mean age of 13.82 years old (ranging from 10.69 to 22.04 years), who had Class I malocclusion and were treated with extraction of four premolars, two maxillary and two mandibular (Tables 4 and 5).

Group 2 consisted of 46 patients treated without extractions, 16 males (34.78%) and 30 females (65.22%) with initial mean age of 14.01 years old (ranging from 11.04 to 21.54 years) (Tables 4 and 5). Both groups were treated with full fixed appliances using the simplified Edgewise technique.

Since previous studies have shown that severity of malocclusion could influence the treatment duration,^{6,10} we further divided each group, based on their initial occlusal index, into two subgroups with different malocclusion severity (high and low). Thus, the four subgroups, two in each group, with high and low initial malocclusion severity had the following characteristics (Table 6).

Subgroup 1A (High severity; $n = 22$) comprised 8 males and 14 females with initial mean age of 13.54 ± 2.18 years (minimum 10.69, maximum 21.25). Subgroup 1B (Low severity; $n = 22$) comprised 6 males and 16 females with a initial mean age of 13.34 ± 1.25 years (minimum 11.15, maximum 15.53). Subgroup 2A (High severity; $n = 15$) comprised 5 males and 10

Table 1 - Criteria applied to score each component of PAR index⁹.

Occlusal relationships		Discrepancy	Score	Weight
POSTERIOR OCCLUSION	Anteroposterior	Good interdigitation – Class I, II or III	0	2
		Less than half of premolar width	1	
		Half of premolar width	2	
	Vertical	No discrepancy in intercuspation	0	2
		Posterior open bite on at least two teeth greater than 2 mm	1	
	Transverse	No cross-bite	0	2
		Cross-bite tendency	1	
		Single tooth in cross-bite	2	
		More than one tooth in cross-bite	3	
		More than one tooth in scissor bite	4	
OVERJET	Positive	0 - 3 mm	0	5
		3.1 - 5 mm	1	
		5.1 - 7 mm	2	
		7.1 - 9 mm	3	
		Greater than 9 mm	4	
	Negative	No discrepancy	0	5
		One or more teeth edge-to-edge	1	
		One single tooth in cross-bite	2	
		Two teeth in cross-bite	3	
		More than two teeth in cross-bite	4	
OVERBITE	Negative	No open bite	0	3
		Open bite less than and equal to 1 mm	1	
		Open bite 1.1 - 2 mm	2	
		Open bite 2.1 - 3 mm	3	
		Open bite greater than or equal to 4 mm	4	
	Positive	Less than or equal to 1/3 coverage of lower incisor	0	3
		Greater than 1/3, but less than 2/3 coverage of lower incisor	1	
		Greater than 2/3 coverage of lower incisor	2	
		Greater than or equal to full coverage of lower incisor	3	
DISPLACEMENT	Crowding Spacing Impaction	0 - 1 mm displacement	0	1
		1.1 - 2 mm displacement	1	
		2.1 - 4 mm displacement	2	
		4.1 - 8 mm displacement	3	
		Greater than 8 mm	4	
		Impacted teeth	5	
Midline		Coincident and up to ¼ lower incisor width	0	3
		Deviated ¼ to ½ lower incisor width	1	
		Deviated more than ½ lower incisor width	2	

Table 2 - Description of variables used.

ABBREVIATIONS	DESCRIPTION
PARi	Initial PAR index
APINH	Initial amount of mandibular crowding
AGE	Age at the beginning of treatment
PARf	Final PAR index
PARi-PARf	Improvement of occlusal discrepancy
PC-PAR	Improvement of occlusal discrepancy (percentage)
Time	Treatment duration in months
IET-PAR	Treatment Efficiency Index

Table 3 - Results of systematic and random errors assessed using depended t-test and Dahlberg's formula.

Variables	1 st Measurement (n = 20)	2 nd Measurement (n = 20)	gl	p	Dahlberg
	Mean $\pm$ SD	Mean $\pm$ SD			
PARI	19.25 $\pm$ 6.07	19.40 $\pm$ 6.28	19	0.527	0.72
PARf	5.00 $\pm$ 3.15	5.25 $\pm$ 3.31	19	0.234	0.65

Table 4 - Compatibility of groups.

Sex	GROUP 1 (Extraction) n = 65	GROUP 2 (Non-extraction) n = 46	Total
Females	41	30	71
Males	24	16	40
Total	65	46	111
$\chi^2 = 0.535$	GL = 1	p = 0.817	

Table 5 - Comparison of the initial characteristics using t-test.

VARIABLES	GROUP 1 (Extraction) n = 65	GROUP 2 (Non-extraction) n = 46	DF	p
	Mean $\pm$ SD	Mean $\pm$ SD		
PARI	19.92 $\pm$ 8.08	17.89 $\pm$ 6.96	109	0.170
CROWDING	4.94 $\pm$ 1.59	4.32 $\pm$ 1.87	109	0.065
AGE	13.82 $\pm$ 2.11	14.01 $\pm$ 1.78	109	0.620

Table 6 - Results of ANOVA and Tukey's test regarding the initial characteristics of subgroups 1A, 1B, 2A e 2B. Subgroups were classified according to their initial malocclusion severity.

Variables	GROUP 1 (Extraction)		GROUP 2 (Non-extraction)		ANOVA	
	Subgroup 1A High Severity n = 22	Subgroup 1B Low Severity n = 22	Subgroup 2A High Severity n = 15	Subgroup 2B Low Severity n = 15	F	p
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD		
PARI	29.09 ^a $\pm$ 5.32	11.68 ^b $\pm$ 2.40	25.60 ^a $\pm$ 5.15	10.87 ^a $\pm$ 2.97	97.28	0.000*
CROWDING	5.17 $\pm$ 1.67	4.64 $\pm$ 1.62	4.08 $\pm$ 2.39	4.19 $\pm$ 1.72	1.35	0.265
AGE	13.54 $\pm$ 2.18	13.34 $\pm$ 1.25	13.88 $\pm$ 1.06	14.09 $\pm$ 1.45	0.79	0.504

* Statistically significant: P < 0.05.

females with a initial mean age of 13.88 $\pm$ 1.06 years (minimum 11.90, maximum 15.82). Subgroup 2B (Low severity; n = 15) comprised 4 males and 11 females with a initial mean age of 14.09 $\pm$ 1.45 years (minimum 11.40, maximum 15.99).

Methods

Clinical records

Patients' orthodontic records were used to obtain the demographic and clinical information included in the analysis: sex, date of birth, age at treatment onset,

proposed treatment protocol, including extraction and non-extraction of premolars, and length of active orthodontic treatment.

To estimate total treatment time, the starting date was defined as the date when placement of first molar bands or first direct bonding occurred, whereas final date was defined as the date when orthodontic retainers were delivered.

Dental cast analysis

Assessment of mandibular crowding

The amount of mandibular crowding was calculated based on the difference between the arch perimeter (circumference measured from the mesial of one permanent first molar to its antimere) and the sum of the mesio-distal width of all mandibular permanent teeth except molars.²⁶

Calculation of occlusal index

The occlusal index was calculated according to the weighted Peer Assessment Rating (PAR index) advocated by DeGuzman et al⁹ which includes the assessment of five occlusal features (posterior occlusion, overjet, overbite, midline and maxillary tooth displacements) with well-defined measurement criteria (Table 1).

The scores for PAR index calculation³⁰ are recorded according to the following:

1. Posterior occlusion.

Posterior occlusion, also described as “buccal segment relationship” in the original PAR index, comprises the zone from the distal anatomical contact point of canine to the mesial anatomical contact point of first permanent molar. Posterior dental relationship is assessed in three planes of space and scores are given to anteroposterior, vertical and transverse discrepancies according to Table 1. These scores are added and the final value is multiplied by two. Each posterior segment, right and left, is recorded separately.

2. Overjet.

Positive or negative overjet is recorded using the most prominent surface of any central or lateral incisors as reference. During this measurement, the ruler is held parallel to the occlusal plane and radial to the line of the arch. The magnitude of the overjet is transformed into a score according to Table 1 and then multiplied by 5.

3. Overbite.

Overbite is recorded as the proportion of the lower incisor crown that is covered by upper incisors or the amount of open bite, in millimeters, taking as reference the tooth with greater overlap. The score obtained according to Table 1 is then multiplied by 3.

4. Midline.

Discrepancy of maxillary midline is assessed in relation to lower central incisors using the score in Table 1 which is then multiplied by 3.

5. Maxillary tooth displacement.

Displacements such as crowding, spacing and impacted teeth are recorded in the maxillary anterior region, only. These occlusal features are recorded considering the shortest distance between contact points of adjacent teeth parallel to the occlusal plane. These measurements are transformed into scores and added according to the criteria defined in Table 1. A tooth is considered impacted when the space available for this tooth is less than 4 mm.

We calculated the PAR index for each of the pretreatment and post treatment dental casts ($n = 222$) using the criteria described above and using the scores specified in Table 1. PAR index was termed initial PAR (PAR_i) when obtained from the pretreatment models, and final PAR (PAR_f) when calculated in post-treatment casts. The higher the numerical value obtained in these indexes, the more severe the malocclusion, because PAR index is obtained by applying scores to the intra-arch (e.g. crowding) and inter-arch (e.g. overbite, overjet, crossbite, midline) dental relationships as well as by using an ordinal scale starting at 0 for a normal value. All measurements in the initial and final casts were obtained using a digital caliper (Mitutoyo, Kawasaki, Japan) with accuracy closed to 0.1 mm.

Assessing changes in occlusal discrepancy

Changes in occlusal discrepancy produced by each treatment protocol were calculated by subtracting PAR_f from PAR_i values (PAR_i - PAR_f). The numerical reduction in the index accounted for occlusal changes directly related to treatment protocol.^{29,30} In addition, the percentage of PAR reduction (PcPAR) during treatment was calculated to verify the amount of improvement produced in relation to the initial severity of malocclusion.^{29,30}

For this calculation, we applied the following mathematical formula:

$$\text{PcPAR} = \frac{\text{PARi} - \text{PARf}}{\text{PARi}} \times 100$$

Treatment efficiency index (TE)

Treatment efficiency was defined as the greatest occlusal index change produced within the shortest treatment time. It was calculated using the following formula, in which the denominator is the total treatment time expressed in months:^{19,31}

$$T_E = \frac{\text{PcPAR}}{\text{TIME}}$$

Statistical analysis

Errors of the method were assessed by repeating the measurements on 20 initial and 20 final dental casts randomly selected from the sample. Repeated measurements were taken approximately one month after the first occlusal index calculation (Table 3). The formula proposed by Dahlberg⁷ ($S^2 = \Sigma d^2/2n$) was applied to estimate random errors, while paired t-test was used to analyze systematic errors.¹⁸

Initial compatibility regarding gender distribution between the two study groups was assessed using the non-parametric chi-square test (Table 4). T-test was also used to assess other baseline characteristics, such as age, malocclusion severity, and amount of mandibular crowding (Table 5). Subgroups 1A, 1B, 2A and 2B were compared using Analysis of Variance (ANOVA). Tukey's test was used to investigate the hypothesis that severity of PARi influences the treatment duration (Tables 6 and 7). Multiple linear regression was used to assess the influence of initial malocclusion severity, mandibular crowding and the extraction/non-extraction protocols over treatment efficiency (Tables 8 and 9). All statistical analyses were performed using Statistica software. P value ≤ 0.05 was considered significant.

RESULTS

No systematic errors¹⁸ were found for repeated measurements one month after the initial assessment. Random errors⁷ were considered negligible (Table 3).

Groups were compatible regarding age, sex, mandibular crowding and PARi (Tables 4 and 5). As shown in Table 6, malocclusion severity was significantly different between subgroups with high PARi (1A, 2A) and low PARi (1B, 2B) severity. The difference between PARi was of approximately 16 points. Subgroups were compatible in all other variables.

Final occlusal outcome, assessed by means of PARf, was similar in all subgroups (Table 7). However, numerical and proportional reduction in the occlusal index was significantly greater in subgroups with high PARi (1A, 2A) than in subgroups with low PARi (2A, 2B). The treatment duration for the non-extraction subgroups was about four (2A) to six (2B) months less than the extraction subgroups; however, treatment time was only significantly reduced in subgroup 2B that started with a low PARi. Treatment was also more efficient in the group with high malocclusion severity treated without extractions (Table 7).

Multiple linear regression analysis showed that of the three variables evaluated (PARi, CROWDING and PROTOCOL), only the treatment protocol with extractions showed significant positive correlation with treatment duration (Table 8). Regarding treatment efficiency, initial malocclusion severity showed a positive influence on the efficiency index, while treatment protocol influenced it negatively (Table 9).

DISCUSSION

Sample and compatibility

The overall objective of this study was to compare two different treatment protocols for Class I malocclusion. For this reason, the sample only included patients with Class I malocclusion who were treated with or without extraction of four premolars. We focused on this specific type of malocclusion because the compatibility of groups regarding initial malocclusion severity decreased the risk of bias. As showed in previous studies, treatment length and efficiency varies according to the amount of initial anteroposterior discrepancy.^{6,19,31,34} Distribution of sex, age, PARi, and mandibular crowding were also compatible between groups, which reduced the risk of confounding and selection bias.

During preliminary data collection, we realized that most patients treated without extractions had mandibular crowding of 8 mm or less, while cases treated with

extractions showed greater amount of crowding. Therefore, we only included patients with initial mandibular crowding not greater than 8 mm in order to eliminate the influence of this variable on the results of our study.³²

Cases that had their initial treatment plan changed during the course of treatment (e.g. non-extraction cases that ended up with extractions) were excluded from the study to avoid the influence of this factor on treatment duration.²¹

The aforementioned inclusion and exclusion criteria were applied to 4000 clinical charts belonging to the Department of Orthodontics' archives of the School of Dentistry — University of São Paulo/Bauru. A sample of 111 subjects was obtained. Considering that the incidence of Angle Class I malocclusion is of approximately 55 %, ¹⁵ we expected to come up with a larger study sample. However, the meticulous application of these criteria resulted in

Table 7 - Comparison of occlusal changes, treatment duration and treatment efficiency between subgroups 1A, 1B, 2A e 2B.

Variables	GROUP 1 (Extraction)		GROUP 2 (Non-extraction)		ANOVA	
	Subgroup 1A High Severity N = 22	Subgroup 1B Low Severity N = 22	Subgroup 2A High Severity N = 15	Subgroup 2B Low Severity N = 1	F	p
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD		
PARf	5.95 $\pm$ 3.93	5.36 $\pm$ 3.92	4.33 $\pm$ 3.90	5.53 $\pm$ 3.44	0.55	0.652
PARI-PARf	23.14 ^a $\pm$ 5.05	6.32 ^b $\pm$ 3.82	21.27 ^a $\pm$ 7.70	5.33 ^b $\pm$ 4.34	60.90	0.000*
PC-PAR	80.00 ^a $\pm$ 12.54	54.81 ^b $\pm$ 32.26	81.36 ^a $\pm$ 17.91	45.74 ^b $\pm$ 40.70	7.40	0.000*
TIME	24.84 ^a $\pm$ 4.18	24.57 ^a $\pm$ 7.33	20.39 ^{ab} $\pm$ 8.15	18.24 ^b $\pm$ 7.24	4.09	0.010*
IET-PAR	3.32 ^{ab} $\pm$ 0.83	2.42 ^a $\pm$ 1.67	4.37 ^b $\pm$ 1.38	3.31 ^{ab} $\pm$ 3.22	3.24	0.027*

* * Statistically significant: P < 0.05.

Table 8 - Multiple regression analysis using treatment duration as a dependent variable.

Variables	Coefficient	SE	t	p
(Constant)	22.748	2.657	8.562	0.0000
PARI	0.031	0.087	0.344	0.7316
CROWDING	0.080	0.389	0.870	0.3864
PROTOCOL	0.332	1.369	-3.593	0.0005*

SE: standard error

R² = 0.1297. Length of treatment = 22.75 + 0.33(Protocol) + 0.080(Crowding) + 0.031 (PARI). *Protocol: 0 – Non-extraction; 1 – Extraction.

Table 9 - Multiple regression analysis using treatment efficiency as a dependent variable.

Variables	Coefficient	SE	t	p
(Constant)	2.075	0.639	3.247	0.0016
PARI	0.238	0.021	2.589	0.0110*
CROWDING	-0.057	0.094	-0.615	0.5397
PROTOCOL	-0.261	0.329	2.808	0.0059*

R² = 0.1149. Treatment efficiency = 2.075 - 0.261(Protocol) - 0.057(Crowding) + 0.238 (PARI). *Protocol: 0 – Non-extraction; 1 – Extraction.

the elimination of a large number of potential participants with Class I malocclusion. The study sample reduced even further because some of the clinical charts did not have the orthodontic documentation that met the specific needs of this study.

METHODS

We used the PAR occlusal index to quantify both, pre-treatment discrepancy and post-treatment occlusal outcomes, since its accuracy and reliability has been previously validated. Moreover, the PAR index is an objective and user friendly analysis method that has been extensively used in similar studies.^{1,4,8,9,13,19,30} Besides allowing us to compare our findings with previous studies, the use of PAR index allowed us to investigate the compatibility of both groups regarding the severity of initial malocclusion,^{4,9,19,29,30} as well as the numerical and the percentage of improvement obtained in each group at the end of treatment. We associated the percentage of occlusal improvement with treatment duration in order to obtain an index capable of objectively expressing the degree of treatment efficiency (T_E), as previously described by other studies.^{19,31}

Lack of significant systematic errors and reduced value of random errors found in this study reflect standardization and accuracy of measurements (Table 3) and are related to the calibration of the examiner prior to data collection. The simple and objective assessment of dental casts by means of PAR index also allowed us to obtain a high degree of precision and reproducibility.

COMPARISON BETWEEN GROUPS AND VARIABLES

Post-treatment occlusal outcomes

The comparison of PARf values between subgroups showed that final occlusal relationships in all subgroups were similarly satisfactory (Table 7). PARf index of non-extraction and extraction groups ranged from 4.33 to 5.95, thus showing a good occlusal outcome in all patients regardless of severity of their initial occlusal discrepancy. These values were similar to those found in prior studies conducted with Class I patients. For instance, Birkeland et al⁴ found PARf values of 5.9 and 6.2 for cases treated with and without extractions, respectively. Likewise, other authors, such as Willems et al,³⁸ Freitas et al,^{8,13} found pooled PARf

values of 5.1, 6.32, and 5.65, respectively. However, these studies used different criteria for sample selection. Birkeland et al⁴ included cases treated with fixed appliances in both maxillary and mandibular arches and cases treated with fixed appliances in a single arch. Willems et al³⁸ included patients treated with removable orthodontic or functional orthopedic appliances and cases treated with fixed appliances in one or two dental arches. Freitas et al^{8,13} only included patients treated with extraction of four premolars and fixed appliances in both dental arches.

Several other studies have assessed the amount of correction of initial occlusal discrepancy using PAR index. Nevertheless, these studies included different types of malocclusion in their samples because their main objectives were to audit the quality of orthodontic treatment provided and the factors that may influence treatment duration and efficiency provided in private practice, university-based and hospital-based clinics. Some of these studies reported similar PARf values,^{6,12,17,24} while others showed higher PARf^{11,12,24,33} and lower PARf values than our study.^{25,28,31,39} The difference in samples and methodology prevented us to make further comparison with these studies.

The high PARf values found in some previous studies were related to cases treated with removable functional orthopedic appliances,^{11,12,24,33} or cases receiving treatment for only one of the dental arches, or the use of historical samples that do not show results as good as recently treated cases.¹¹ Additionally, the experience of the treatment provider was also found to be directly associated with the quality of occlusal outcomes.^{11,12,28,31,33} Moreover, the common characteristic among studies that showed low PARf values was that orthodontic treatment was provided by a certified specialist, regardless of being a private or public setting.

Treatment-related occlusal improvement

The amount of occlusal improvement, measured as the numerical and percentage reduction in PAR index, was significantly greater in subgroups with high initial malocclusion severity (1A and 2A) than in subgroups with low initial malocclusion severity (1B and 2B) (Table 6). The direct correlation between the amount of initial occlusal discrepancy and

the amount of occlusal improvement has been previously reported.^{4,6,12,13,24,27,33} The higher the initial occlusal discrepancy, the greater reduction in PARf and the greater percentage of occlusal improvement.

For instance, Robb et al³¹ observed percentages of PAR index reduction of 84.5% in adults and 88.1% in adolescents while Woods, Lee and Crawford,³⁹ found 82.2% and 87.2% of occlusal improvement in patients treated with and without extractions, respectively. These high levels of occlusal improvement could be attributed to the inclusion of patients with high PARi (24.9 to 26.6) treated by specialist in private practices.^{11,12,28,33}

Treatment duration

To analyze treatment duration, we took into account initial malocclusion severity (high and low) and differences between subgroups regarding age, sex, mandibular crowding, and dentition. Our results showed that patients treated without extractions had overall shorter treatment than those treated with extraction of four premolars. However, difference was significant only in the non-extraction subgroup with low severity (Table 7). As shown in the multiple regression analysis and in agreement with previous studies,^{6,10,34} extractions had a direct incremental effect on the length of treatment (Table 8). Our results corroborate the conclusions by Turbill, Richmond and Wrigh,³⁴ indicating that treatment with extractions in Class I malocclusion has an additional phase (closure of extraction spaces) as compared to treatment without extractions, thus resulting in increased total treatment time.

Previous studies have shown that there is a direct influence of initial malocclusion severity over treatment duration, meaning that severe malocclusions require longer treatment time,^{6,10}. Our findings, however, are similar to Grewe and Hermanson's¹⁶ results:

we did not find a significant correlation between initial malocclusion severity and treatment duration.

Total treatment time found in our study was similar to several other studies investigating Class I malocclusion. For instance, Wes Fleming et al³⁷ reported a treatment time of 20.6 ± 6 months for non-extraction cases, whereas Freitas et al^{8,13} and Nakamura²³ reported treatment times of 24.96, 25.08 and 28.95 months, respectively, for patients treated with extractions. Kocadereli²² found greater treatment time for non-extraction and extraction cases, 26.35 ± 13.25 months and 31.53 ± 14.10 months, respectively. Interestingly, Germec and Taner¹⁴ found that borderline Class I cases treated with extraction lasted 24.8 ± 6.9 months while those treated with stripping lasted 17 ± 4.6 months. On the other hand, Skidmore et al³² reported that treatment duration of their Class I sample was 21.9 months, despite the fact that they used different treatment protocols. Minor variations in treatment time between studies are probably related to differences in methodology and sample.

Treatment efficiency

Treatment efficiency is defined as the satisfactory occlusal relationship obtained within the shortest treatment time, assuming that the outcomes meet clinician's and patient's expectations. Treatment efficiency index allowed us to objectively assess and compare the degree of efficiency of the two protocols used in this study.

Results showed a higher efficiency ratio (4.37) for the subgroup with high malocclusion severity treated without extractions and a lower efficiency ratio (2.42) for the subgroup with low severity treated with extractions (Table 7), while the two other subgroups showed an intermediate value (3.3). These findings were mainly due to the following factors:

Initial malocclusion severity

Similarly to previous studies,^{4,6,12,13,24,27,33} our results revealed a direct relationship between initial malocclusion severity and its correction, as analyzed numerically and in percentage (Table 7). Thus, knowing that the percentage of correction (PcPAR) has a direct relationship with efficiency, it would be expected that initial severity also influence it, as shown by multiple regression analysis (Table 9). Therefore, treatment efficiency was positively influenced by high initial occlusal discrepancy (subgroups 1A and 2A) and negatively influenced by low initial severity (subgroups 1B and 2B).

Treatment duration

While the occlusal changes resulting from treatment have a proportional relationship with efficiency ratio, treatment duration showed an inversely proportional relationship.^{19,31} Thus, the lower values in the length of treatment in subgroups treated without extractions resulted in higher values for the efficiency ratio.

Treatment protocol

The multiple regression analysis showed a direct relationship between the extraction protocol and longer treatment time (Table 8), and an inverse relationship with the efficiency ratio (Table 9). This result was expected, as several studies have also shown a direct relationship between the number of extractions and a longer treatment time,^{6,10,20,34} which suggests that extractions negatively influence treatment efficiency.

Therefore, the significant greater efficiency found in the subgroup with high PARi values treated without extractions (subgroup 2A) was mainly due to the positive influence of a high value of initial severity

and treatment protocol. An opposite effect was observed in the subgroup with low PARi treated with extractions (subgroup 1B), which showed a low efficiency index.

Clinical considerations

Extraction of permanent teeth for orthodontic purposes has been used for a long time.^{5,36} However, the controversy surrounding its use is far from being resolved. The popularity of extraction and non-extraction protocols have alternated in orthodontic history,^{5,36} showing a “pendulum” effect, i.e., favoring one protocol for a period of time and then the other in the next period. New appliances and techniques have also influenced the use of tooth extraction as part of the orthodontic treatment (e.g. cephalometry, expanders, distalization, brackets, archwire alloys).³⁶ Currently, the search for better esthetic, functional and stable results has decreased this discussion, and extractions are more accepted as means and not as objectives of orthodontic treatment. Its use has also decreased and it is only considered after careful evaluation of all factors involved in each particular case.^{19,20,22,35}

In this study, we found that initial malocclusion severity did not significantly influence the duration of orthodontic treatment. However, initial severity was directly related to the amount of its correction and, as a consequence, to a higher degree of efficiency, which corroborates the results reported in previous studies.^{4,6,12,13,24,27,33}

Extraction of premolars as part of Class I treatment showed a direct relationship with treatment duration and an inverse relationship with treatment efficiency. This positive relationship between the extraction of premolars and treatment duration had already been observed in other studies;^{6,10,34} however, the high heterogeneity of the methodology,

sample, types of malocclusion, and appliances used limited the application of their results to specific situations, such as treatment of Class I malocclusion. Moreover, Beckwith et al³ showed that there was no relationship between extractions and an increased treatment time, making it difficult to generalize these conflicting results.

The treatment objectives regarding the occlusal outcomes in all subgroups were the same (tooth alignment, ideal overjet and overbite, and maintenance of Class I molar relationship). Therefore, the main difference between groups was whether or not their treatment included extraction of four premolars. The greater treatment time in the extraction group could be explained by the need for an additional phase that involved closure of the extraction space by retraction of maxillary and mandibular anterior teeth. The size of the remaining extraction space depended on the amount of initial crowding.³⁴

This study confirms the positive influence of initial malocclusion severity on treatment efficiency and the negative influence of dental extractions on

orthodontic treatment duration. Clinicians can expect satisfactory occlusal outcomes with a greater amount of correction in cases with severe occlusal discrepancy and a longer treatment time when it involves dental extractions. Our findings can be used to inform patients and parents about the expected treatment time for correction of Class I malocclusion. Additionally, it can be used to calculate professional fees.

CONCLUSIONS

The methodology and results of this study led us to the following conclusions:

1. Occlusal outcomes were satisfactory and similar in the four subgroups evaluated, regardless of the protocol (extraction or non-extraction) used.
2. Initial malocclusion severity showed a significant direct relationship with the amount of occlusal improvement and with the efficiency ratio; but no influence on orthodontic treatment duration.
3. Extraction of premolars for treatment of Class I showed a direct relationship with treatment duration and an inverse relationship with treatment efficiency.

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Comparative study of dental cephalometric patterns of Japanese-Brazilian, Caucasian and Mongoloid patients

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Introduction: The objective of this study was to identify the patterns of dental variables of adolescent Japanese-Brazilian descents with normal occlusion, and also to compare them with a similar Caucasian and Mongoloid sample.

Methods: Lateral cephalometric radiographs were used to compare the groups: Caucasian (n = 40), Japanese-Brazilian (n = 32) and Mongoloid (n = 33). The statistical tests used were one-way ANOVA and ANCOVA. The cephalometric measurements used followed the analyses of Steiner, Tweed and McNamara Jr.

Results: Statistical differences ($P < 0.05$) indicated a smaller interincisal angle and overbite for the Japanese-Brazilian sample, when compared to the Caucasian sample, although with similar values to the Mongoloid group.

Conclusion: The dental patterns found for the Japanese-Brazilian descents were, in general, more similar to those of the Mongoloid sample.

Keywords: Ethnic group. Reference standards. Orthodontics.

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

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INTRODUCTION

In 1899, when the study of malocclusion was limited to dental casts, Angle proposed his classification.² Since then, several authors have dedicated to improve the diagnosis methodology used at that time.¹

The creation of cephalostat enabled us to study the alterations that occur in the face and cranium, which, in turn, allowed us to make better diagnoses and conduct more accurate treatment. As a consequence, it became necessary to determine standard variables to guide interpretation of results. Additionally, it also became interesting to study the mean cephalometric values of groups with normal occlusion and satisfactory skeletal pattern. Therefore, many analysis methods were created and Downs,⁶ Tweed,²⁷ Steiner²⁴ as well as many others explored the development of standards that would give support to the clinical field.

It is known that skeletal and facial structures directly influence the position of upper and lower teeth as well as the appearance of the facial profile. Therefore, the mean cephalometric variables must be explicit to the orthodontic community in order to improve treatment offered to patients, including descendants of different races. This is due to the fact that the relation of normality between skeletal and dental positions may be greatly

diverse due to ethnic variations^{22,25}. Thus, this was the basis on which this study was conducted.

Keeping those reflections in mind,^{6,26} the objective of this research was to determine the mean dental cephalometric variables of young Japanese-Brazilian descendants with normal occlusion, and compare the results with the values of two other groups: Caucasian and Mongoloid. Although many papers on cephalometry are available in the scientific literature, to date, no research has been conducted on this subject.

MATERIAL AND METHODS

Material

The sample comprised 105 lateral cephalometric radiographs of 32 young Japanese-Brazilians, 40 young Caucasian subjects and 33 young Mongoloid, all with normal occlusion and well balanced face. Radiographs were retrieved from the archives of the Department of Orthodontics, School of Dentistry, University of São Paulo/Bauru.

The sample presented with all permanent teeth in occlusion (the presence of second and third molars was optional), absence of orthodontic treatment, normal occlusion or Class I malocclusion. Crowding not greater than 2 mm was acceptable (Fig 1).



Figure 1 - Occlusal characteristics of a female patient from the Japanese-Brazilians sample.

Caucasian and the Mongoloid samples should have both parents Caucasian and Mongoloid, respectively. This means that there was an absence of racial miscegenation. On the contrary, the Japanese-Brazilian sample was represented by descents of both Caucasian and Mongoloid.

There was also the concern of selecting a nearly identical number of boys and girls for the samples of Caucasian (20 of each sex), Japanese-Brazilian (17 females and 15 males) and Mongoloid (17 females and 16 males), thus providing homogeneous groups in relation to sex.

Methods

The three groups were radiographed in maximum intercuspation, since the difference between this position and the mandibular centric relation is minimal at this age and slightly affects the cephalometric results, especially in cases of normal occlusion.³⁰

After the anatomical drawing, landmarks were identified and subsequently scanned using Numonics, AccuGrid A30TL (Numonics Corporation, Montgomeryville, PA, USA). The magnification factor was corrected (6% for the Caucasian sample, 9.8% for the Japanese-Brazilian sample and 7% and 8% for the Mongoloid sample) by the software itself.

The variables studied were: 1.NA, 1-NA, 1-Aperp, 1.NB, 1-NB, 1-AP, IMPA, I Line, I.1, Overjet and Overbite (Fig 2).

Method error

Tracings and measurements were performed by the same examiner who also transferred data to the software Dentofacial Planner 7.02 (Dentofacial Planner Software Inc., Toronto, Ontario, Canada). After

twenty days, 20 radiographs were randomly selected and retraced (both manually and digitally) to determine reliability of results.

Systematic and random errors were evaluated independently for each variable. T-test was used to calculate systematic error,¹¹ whereas Dahlberg's formula was used to calculate random error (Table 1).

Descriptive and comparative analyses

Before proceeding with descriptive and comparative analyses, the variables were submitted to Kolmogorov-Smirnov test which confirmed the normal distribution of the samples and allowed the use of parametric tests.

Due to lack of compatibility between patients' age in the Mongoloid group and to avoid interference in the results, ANCOVA (covariance analysis) test was performed with patients' age considered as the adjustable variable, thereby permitting approximation of values. The results obtained showed that age did not influence any of the studied variables, thus allowing reliable statistic comparison. ANOVA test was used to compare patients' age (Table 2). Results were considered statistically significant for $P < 0.05$. All aforementioned tests were performed using Statistica for Windows 7.0 software (Statistica for Windows 7.0 Copyright StatSoft. Inc. Tulsa, Okla, USA. <http://www.statsoft.com>).

RESULTS

Random and systematic error

Table 1 presents the statistical analysis performed to assess intra-examiner error. Systematic errors were found in four variables and random errors were considered acceptable.

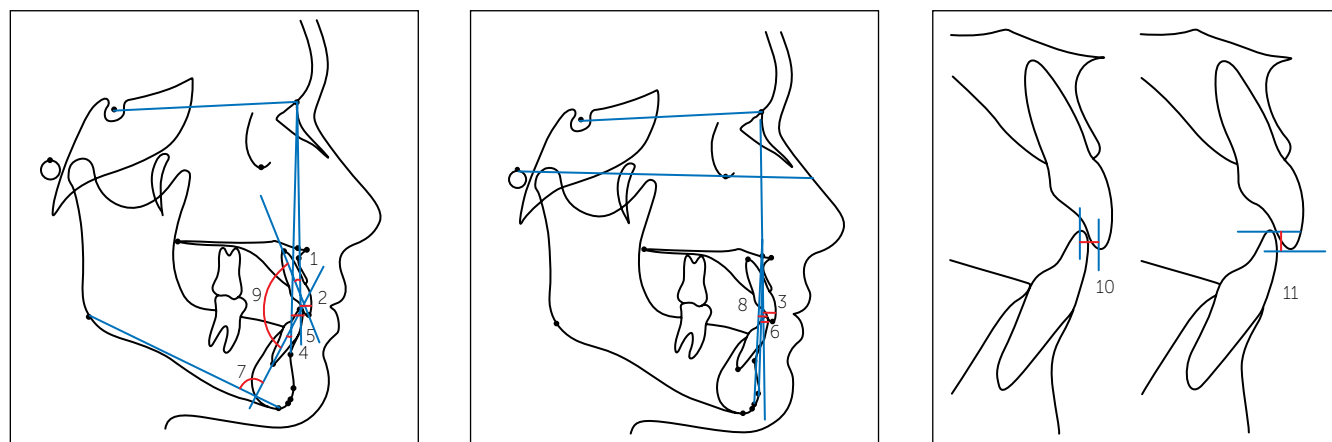


Figure 2 - Cephalometric variables.

Table 1 - Random error (Dahlberg formula) and systematic error (t test)

Variable	1 st Tracing Mean $\pm$ SD	2 nd Tracing Mean $\pm$ SD	Dahlberg	p
1.NA	24.62 $\pm$ 4.52	25.16 $\pm$ 4.20	1.410	0.518
1-NA	5.32 $\pm$ 2.22	5.25 $\pm$ 2.14	0.510	0.583
1-Aperp	6.35 $\pm$ 1.86	6.18 $\pm$ 1.73	0.422	0.240
1.NB	26.36 $\pm$ 7.48	26.99 $\pm$ 8.09	0.956	0.032*
1-NB	5.24 $\pm$ 2.49	5.29 $\pm$ 2.46	0.347	0.593
1-AP	3.47 $\pm$ 2.32	3.55 $\pm$ 2.34	0.208	0.258
IMPA	92.02 $\pm$ 7.94	92.52 $\pm$ 8.63	0.961	0.219
I Line	-3.99 $\pm$ 2.52	-4.24 $\pm$ 2.44	0.250	0.031*
1.1	126.95 $\pm$ 10.35	125.81 $\pm$ 10.22	1.263	0.047*
Overjet	2.82 $\pm$ 0.88	2.62 $\pm$ 0.72	0.272	0.011*
Overbite	2.22 $\pm$ 1.26	2.05 $\pm$ 1.14	0.293	0.177

* Significant for P < 0.05.

Table 2 - Minimum, maximum and mean age of Caucasian, Japanese-Brazilian and Mongoloid samples. ANOVA followed by Tukey test.

Age	Caucasian		Japanese-Brazilian		Mongoloid	
	Male	Female	Male	Female	Male	Female
Minimum	12.00 ± 12.00		12.97 ± 11.83		11.84 ± 8.35	
Maximum	14.92 ± 14.92		16.62 ± 15.36		21.99 ± 18.46	
Mean	13.57 ± 13.70		14.79 ± 13.22		15.56 ± 15.65	
ANOVA followed by Tukey test						
	Caucasian		Japanese-Brazilian		Mongoloid	
Overall mean	13.64 ^a		13.96 ^a		15.61 ^b	
					P	
					0.000*	

* Significant for P < 0.05.

Different letters account for significant differences.

Age means

In order to analyze the minimum, maximum and mean age of Caucasian, Japanese-Brazilian and Mongoloid groups, the samples were separated by sex (Table 2).

Comparative analysis between groups

ANCOVA was applied to verify potential differences between groups (Table 3).

DISCUSSION

Due to being practical and of simple comprehension, cephalometry is still frequently used for orthodontic teaching. Undergraduate students with little experience need clear and well-defined parameters to understand the purposes and limitations of orthodontic treatment. With practice, the student gradually

gets rid of rigid numbers and goes on to value other subjective aspects such as patient's face, profile and expectations. However, it is impossible to bring forth maturity before establishing the goals and patterns of normality.^{12,24}

As for more experienced orthodontists, cephalometric values are the possibility to locate and quantify the problem, which allows them to choose the most appropriate treatment for the patient.

The authors who laid the groundwork of cephalometric analysis developed their norms based on Caucasian samples.^{6,16,24,26} Later on, it was suggested that differences in normality values existed between different racial groups.^{5,7,10,18,19}

With these reasons in mind, the need to specify the cephalometric pattern for Japanese-Brazilians (descendants of Caucasian Brazilians and Japanese) became evident.

Table 3 - Comparison between groups. ANCOVA and Tukey test.

Variable	Caucasian Mean $\pm$ SD	Japanese-Brazilian Mean $\pm$ SD	Mongoloid Mean $\pm$ SD	p value age	p value group
Upper incisor in relation to the maxilla					
1.NA	21.69 $\pm$ 5.50	24.80 $\pm$ 5.87	23.14 $\pm$ 6.88	0.246	0.074
1-NA	4.08 $\pm$ 2.07	4.77 $\pm$ 2.04	4.49 $\pm$ 2.37	0.661	0.432
1-APerp	5.24 $\pm$ 1.53	6.08 $\pm$ 1.79	5.56 $\pm$ 1.81	0.900	0.122
Lower incisor in relation to the mandible					
1.NB	25.95 $\pm$ 5.57	27.70 $\pm$ 7.39	28.54 $\pm$ 4.74	0.273	0.095
1-NB	4.38 ^a $\pm$ 1.63	5.29 ^{ab} $\pm$ 2.29	5.70 ^b $\pm$ 1.93	0.647	0.017*
1-AP	2.32 ^a $\pm$ 1.80	3.11 ^{ab} $\pm$ 1.95	3.47 ^b $\pm$ 1.80	0.903	0.042*
IMPA	92.50 $\pm$ 6.65	93.40 $\pm$ 8.53	93.95 $\pm$ 6.07	0.369	0.497
I line	-2.83 ^a $\pm$ 1.84	-3.82 ^{ab} $\pm$ 2.17	-4.22 ^b $\pm$ 1.85	0.584	0.010*
Relationship between incisors					
1.1	130.09 ^a $\pm$ 7.96	124.88 ^b $\pm$ 9.62	125.39 ^b $\pm$ 7.79	0.054	0.004*
Overjet	2.66 $\pm$ 0.66	2.96 $\pm$ 1.22	2.79 $\pm$ 0.76	0.225	0.285
Overbite	2.99 ^a $\pm$ 1.15	2.23 ^b $\pm$ 1.40	2.57 ^{ab} $\pm$ 1.11	0.138	0.041*

* Significant for $P < 0.05$.

Different letters account for significant differences.

Method error

For random errors, the limits for the linear variables were set at 1 mm, whereas for the angular variables they were set at 1.5°. Important random errors were not found (Table 1).

Among the 11 studied variables, four presented statistically significant differences between the first and the second measurements (Table 1).

Since the variables were used for comparison purposes,²⁴ the application of these values was considered reliable. Additionally, the absence of random errors increases reliability of results.

The sample

In order to standardize the results, the sample was selected on the basis of patients' lineage and occlusion. This is because gathering a sample in which other variables are equivalent allows us to obtain results derived solely from racial differences between groups. Clearly, the strict inclusion criteria applied to the sample limited its size. However, a choice was made to sacrifice the number of subjects included in the research in order to enhance homogeneity of the sample. Before comparing the groups, a comparison

between patients' sex was performed.⁷ Since no statistically significant differences were found between them, both male and female patients were included in all three groups (Table 3).

The age group of choice was based on Ceylan, Baydas and Bolukbasi's⁴ findings in which the majority of patients submitted to orthodontic treatment is aged between 10 and 14 years old. Therefore, this age group has priority in obtaining standard norms. Additionally, determining a particular age group favors comparisons with past and future studies.

The choice of variables

The criteria applied in selecting the variables were based on reliability, but also on frequency of their use in orthodontics.¹² This facilitates a rapid visualization of results and future comparisons with other studies.

Only statistically different variables were discussed after comparison with the Caucasian and Mongoloid groups (Table 3). These variables were gathered according to their representativity so as to facilitate comprehension. Results were discussed focusing on the Japanese-Brazilian sample and their differences to the Caucasian and Mongoloid samples.

Lower incisors linear alterations (1-NB, 1-AP and I Line)

The Japanese-Brazilian sample showed accentuated protrusion of lower incisors. Their values were in between those of the Caucasian and Mongoloid samples. It is worth noting that all three linear variables concerning the horizontal position of incisors showed the same behavior, thereby indicating statistic similarity between the Japanese-Brazilian and the other samples. Moreover, all variables showed greater protrusion of lower incisors when the Mongoloid were compared to the Caucasian sample.

Miura, Inoue and Suzuki¹⁸ also observed great protrusion of Japanese lower incisors in comparison to Caucasian. The results found by Uesato et al,²⁸ Engel and Spolter,⁷ Miyajima et al,¹⁹ Raddi²³ and Takahashi²⁵ also demonstrate greater protrusion of lower incisors in Asiatic samples.

Incisors positioning strongly influences the lower third of the face,^{16,29} specially the lower lip.^{8,9}

It is important to observe that the values found for Japanese-Brazilian sample were in an intermediary rank in relation to the Mongoloid and Caucasian samples. This fact may be caused by the miscegenation of this group, since these results were similar for all three variables.

Upper and lower incisors angular relationships (1.1 and Overbite)

These variables were expected to present statistically significant differences, since some dental variables of the Japanese-Brazilian sample were numerically different from the Caucasian and Mongoloid samples (Table 3).

Variable 1.1 (interincisors angle) in the Japanese-Brazilian sample exhibited lower values than in the Caucasian sample and was similar to the Mongoloid sample, thus representing greater vestibular inclination of incisors among Japanese-Brazilian and Mongoloid, which corroborates the findings of Miura, Inoue and Suzuki¹⁸.

Values found for overbite also suggest vestibular inclination: the Caucasian sample presented greater overbite than Japanese-Brazilian and Mongoloid samples, which is in agreement with Engel and Spolter's⁷ studies. This may be explained by the fact that greater buccal inclination of incisors reduces vertical

trespass, which was also observed by Iwasawa, Moro and Nakamura.¹⁴

Both interincisors angle and overbite are deeply connected to the angular position of upper and lower incisors.^{15,20} Thus, it is possible to affirm that this characteristic was the determining factor for variable 1.1 to present smaller values than the Caucasian sample, thereby reinforcing the understanding of a more vestibular inclination of lower incisors.¹⁵ Additionally, it is possible to suggest that this vestibular inclination influenced overbite results.^{15,20}

General considerations

The results yielded by orthodontic treatment in contemporary society not only have to establish a functional and balanced occlusion, but also have to provide pleasant facial esthetics.¹⁷

Therefore, the expectation of producing facial improvements as a result of tooth movement remains evident, since there is an intimate connection between labial posture and subjacent structures such as the teeth and the alveolar process.

Accepting that environmental influences play an important role in orthodontic treatment and its esthetic results is critical to understand the value and necessity of individualized orthodontic treatment as well as the study of specific norms concerning ethnic groups from different backgrounds.

Considering the anthropological differences of facial and dental patterns, Miura, Inoue and Suzuki¹⁸ compared a Mongoloid sample with the values of Steiner's analysis. The authors concluded that treatment objectives set for Japanese must be different from those set for Caucasians.¹⁸

Miura, Inoue and Suzuki¹⁸ assert that results produced by orthodontic treatment performed in Japanese patients will not be more functional, stable or desirable if we use smaller values for the variables ANB, 1.NA, 1-NA, 1.NB and 1-NB, as advocated by Steiner for American patients.

This means that, in spite of the amount of researches addressing cephalometric patterns, the professional must be wise in order to make good use of these norms. Simply knowing so many different patterns and analyses is not sufficient. The orthodontist must have the ability to apply such knowledge to each specific case.²⁸

Since the mean values change according to the sample and depend on the locality of the study, we would agree that individualized values are more applicable. After all, different ethnic groups need different cephalometric patterns.

In general, we may say that the most important factor clinically exhibited by young Japanese-Brazilian in this study is the greater buccal inclination and protrusion of incisors. This aspect must be considered when choosing a treatment protocol. Bearing in mind that this ethnic group frequently presents protrusion and crowding, it is necessary to take into account the limitation of these patients in relation to the amount of incisor retraction.

Furthermore, oral muscles are strong enough to cause treatment relapse. Even the position of lips influences incisors stability and alignment.

Therefore, the decisions about the need for extractions and type of mechanics should be made on the basis of these circumstances.²¹ In case of doubt, it is essential to consider that, to this group, it is more adequate to place lower incisors in a more anterior position, which reduces the indication of extractions in borderline cases. In those cases, only interproximal wear would be able to provide dental alignment.

Therefore, in addition to considering patient's needs, the orthodontist should also know the values of normality for Japanese-Brazilian patients in order to choose the best treatment plan. In clinical terms, we can apply the same principles when selecting pre-adjusted brackets for Class I and II malocclusions cases. In other words, it is possible to apply the results of interincisors angle and overbite found in this research in order to choose the most adequate orthodontic accessories. Brackets used to correct Class I and Class II malocclusion exert greater

buccal inclination on lower incisors, whereas those used to correct Class III malocclusion exert greater buccal inclination on upper incisors.³

Therefore, a combination of these different prescriptions would allow greater upper and lower buccal tipping and, as a result, could offer more satisfactory esthetic outcomes, in addition to increasing case stability.

In short, based on the results of this study, the objectives of orthodontic treatment conducted with Japanese-Brazilian patients (Mongoloid and Caucasian descendent), must be different from those of Caucasian Brazilian patients.

According to the literature, the use of specific and individualized patterns helps to achieve treatment stability¹⁸ and adequacy of bone, dental and tegumentary structures.^{18,19}

Applying these variables to Japanese-Brazilian born in Brazil allows us to provide more stable and esthetic results. Last but not least, the study by Miyajima et al¹⁹ reveals the rebirth of an ethnic pride, particularly in large urban centers. Furthermore, there is a growing demand for exclusive orthodontic treatment based on patterns directed towards specific ethnic groups.¹³

CONCLUSIONS

Based on the methodology applied and on the results of this research, it is possible to conclude that the sample of Japanese-Brazilian presents:

1. Smaller values for interincisors angle and overbite in relation to the Caucasian sample, but close to Mongoloid values.
2. Young Japanese-Brazilians present, in general, intermediate numerical values that are in between the samples studied. Nevertheless, Japanese-Brazilian are more similar to Mongoloids than to Caucasians.

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Skeletal maturation in individuals with Down's syndrome: Comparison between PGS curve, cervical vertebrae and bones of the hand and wrist

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Introduction: This study was conducted with the aim of adapting the methods developed by Martins and Sakima to assess skeletal maturation by cervical vertebrae in the pubertal growth spurt (PGS) curve. It also aimed to test the reliability and agreement between those methods and the method of hand and wrist radiograph when compared two by two and all together.

Methods: The sample comprised 72 radiographs, with 36 lateral radiographs of the head and 36 hand-wrist radiographs of 36 subjects with Down's syndrome (DS), 13 female and 23 male, aged between 8 years and 6 months and 18 years and 7 months, with an average age of 13 years and 10 months.

Results and Conclusions: Results revealed that adapting the methods developed by Martins and Sakima to assess skeletal maturation by cervical vertebrae in the curve of PGS is practical and useful in determining the stage of growth and development of individuals. The stages of maturation evaluated by cervical vertebrae and ossification centers observed in radiographs of the hand and wrist were considered reliable, with excellent level of agreement between the methods by Hassel and Farman as well as Baccetti, Franchi and McNamara Jr and Martins and Sakima. Additionally, results revealed an agreement that ranged between reasonable to good for the three methods used to assess the skeletal maturation, showing statistical significance.

Keywords: Down's syndrome. Cervical vertebrae. Age determination by skeleton. Sesamoid bones.

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INTRODUCTION

The literature does not reach a consensus regarding the use of chronological age to estimate the start and end of facial growth. In other words, it is not considered a reliable parameter to assess the stage of pubertal growth of an individual. Skeletal maturation is influenced by constitutional-genetic, hormonal, nutritional, socio-economic, climatic and seasonal as well as biochemical-pharmacological factors, which may delay or speed up due to several diseases. The Down's syndrome is among the most frequent causes of skeletal age retardation.²²

Over the past years, the interest in studying individuals with chromosome 21 trisomy or Down's syndrome (DS) has increased. The pattern of skeletal maturation in individuals with DS has been widely investigated because the reports on the bone age of these individuals are controversial.^{4,18} The literature reports methods that are employed to determine the biological age of individuals without Down's syndrome; however, it is not known for certain the validity of these methods in a syndromic population.

The methods considered as reliable references to identify the stages of maturation during the pubertal growth spurt (PGS) are hand and wrist radiography,^{6,8,13,23} lateral cephalometric radiograph,^{3,17,21} or both.^{2,19}

In 1949, Greulich and Pyle¹³ observed variations in the bone structures revealed by 60 radiographs of the hand and wrist, from birth to adulthood. This study originated an atlas that included the average data of alterations and provided the parameters of normality that serve as the basis for research and diagnostics of ossification centers. In addition, Fishman⁸ proposed a method for radiographic evaluation of the Skeletal Maturation Index (SMI) of which 11 indicators are evinced during adolescence. The sequence of the four stages of maturation, which proved stable, progressed by the increase in width of the selected epiphyseal, ossification of the adductor sesamoid, capping of the epiphysis over the shafts and finally their merging. Martins and Sakima²³ advocated the graph of the PGS curve with the sequence of mineralization phase of ossification centers of the hand and wrist, determining whether the rate of growth was in ascending or descending phase.

Hassel and Farman¹⁷ assessed the stage of skeletal maturation of the cervical vertebrae and proposed a variation of the method advocated by Lamparski,²¹

correlating lateral cephalometric radiographs with radiographs of the hand and wrist. As a result, they established six stages of maturation and concluded that it is possible to determine reliable positions in relation to the degree of skeletal maturation in cervical vertebrae and the potential for future growth of individuals. Reproducibility of this method was proved by Santos et al,²⁹ thus corroborating the results by Hassel and Farman.¹⁷ Baccetti, Franchi and McNamara Jr,³ who described a new version for the review of the Stages of Maturity in these bones in order to detect the moment when an individual is at the peak of mandibular growth. Their method was based on the changes in size and shape of the vertebral body, and establishes five stages of maturation instead of six, as in the method of Hassel and Farman.¹⁷

In the literature, there are studies reporting the level of agreement between the ossification centers of the hand and wrist and the cervical vertebrae maturation (CVM). These studies obtained statistically significant results proving the reliability of the tested methods.^{2,19,30}

Although the indexes for each stage of skeletal maturation are estimated, the issue related to the type of classification exists. In other words, the analysis by Martins and Sakima²³ enables one to determine the individual's exact location in the PGS curve, what does not occur in the subjective methods of CVM by Hassel and Farman¹⁷ as well as Baccetti, Franchi and McNamara Jr,³ both of which allow the pubertal growth stage to be estimated. Therefore, this study proposes an adaptation of the methods developed by Martins and Sakima²³ used to assess cervical vertebrae maturation (CVM) in the PGS curve, as well as to determine reliability and agreement among the methods when compared two by two and all together.

MATERIAL AND METHODS

The sample comprised 72 radiographs, 36 lateral cephalometric radiographs and 36 radiographs of hand and wrist from 36 individuals with Down's syndrome aged between 7 years and 8 months and 18 years and 9 months. Methods were based on the agreement analysis of three distinct methods used to assess skeletal maturation: Martins and Sakima,²³ for hand and wrist radiographs; Hassel and Farman¹⁷ as well as Baccetti, Franchi and McNamara Jr³ for lateral cephalometric radiographs by means of cervical vertebrae observation.

For each one of the CVM assessment methods^{3,17} the subjects were classified according to their maturation stage or index. Nevertheless, all methods classified each phase of maturation differently, that is, the first comprises six stages of maturation, whereas the second comprises five stages. Therefore, adjustments were made in order to visualize each method in the PGS curve, as well as in the method developed by Martins and Sakima,²³ allowing statistical analysis to be carried out with the same type of classification.

Adaptation process to visualize the CVM by Hassel and Farman's method¹⁷ in the PGS curve

The stages of maturation have their own characteristics, so the morphological changes indicate different expectations of growth and development for the individual characterized by narrowing of the intervertebral space and changes in the contour of the vertebrae. Hassel and Farman¹⁷ separated Fishman's⁸ 11 skeletal maturation indexes (SMI) and correlated them with the shape of the contour of the cervical vertebrae (C2, C3 and C4), thus creating six distinct stages (Fig 2).

The adaptation of Hassel and Farman's¹⁷ stages was possible due to the correspondence between CVM 1 and Fishman's⁸ SMI 1 and 2, located at the beginning of Martins and Sakima's²³ curve. Examinations performed to assess the cervical vertebrae revealed that Hassel and Farman's¹⁷ method comprised the highest number of stages: six stages against five for Baccetti, Franchi and McNamara Jr's.³ For this reason, it was necessary to divide the six stages in the PGS curve developed by Martins and Sakima²³ (Fig 3).

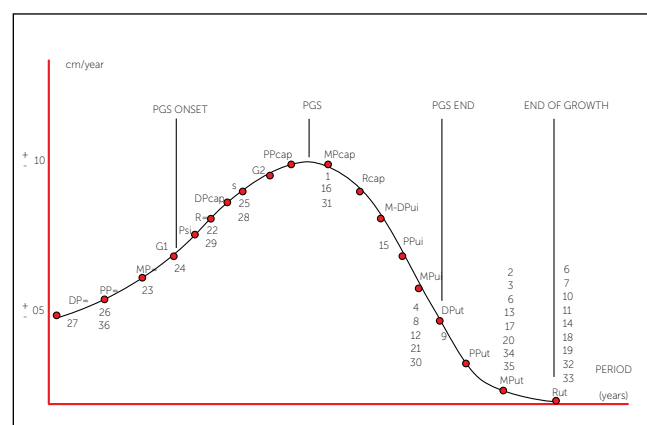


Figure 1 - Graphical representation of individuals distributed in the PGS curve.

Adaptation process to visualize the CVM by Baccetti, Franchi and McNamara Jr's method³

Baccetti, Franchi and MacNamara³ proposed a new visual method which consisted on assessing the morphological characteristics of three cervical vertebrae (C2, C3 and C4) and included five stages (CVM I to V). Similarly to the method by Hassel and Farman,¹⁷ the five stages of Baccetti, Franchi and McNamara Jr³ had to be adapted in the PGS curve (Fig 4).

This adaptation was performed according to reports provided by the authors, especially with regards to the mandibular growth peak occurring between CVM II and III and which is not achieved without CVM I and II. CVM V is recorded at least two years after the growth peak. For example, the peak of mandibular growth occurs within one year after the CVM II stage. Thus, this phase ranges from G1 to the peak of PGS, and according to Martins and Sakima,²³ the G1 phase begins 1 year before reaching the peak of PGS. Figure 4 depicts where each CVM stage is located in the pubertal growth curve.

The methods used in this study allowed us to superimpose the visualization techniques of cervical vertebrae maturation over the PGS curve. New scores were assigned after dividing growth curve into five stages of ossification: A, B, C, D and E. These stages correspond to a group of ossification phenomena present in the PGS curve (Fig 5).

Two weeks after assessing lateral cephalometric radiographs (T_1) by the methods developed by Hassel and Farman¹⁷ as well as Baccetti, Franchi and McNamara Jr,³ and after assessing the hand and wrist radiographs by the method developed by Martins and Sakima,²³ the tests were repeated (T_2).

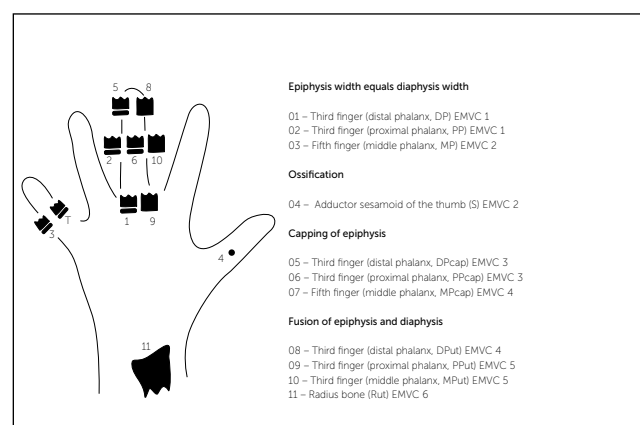


Figure 2 - Fishman's⁸ indicators of skeletal maturation.

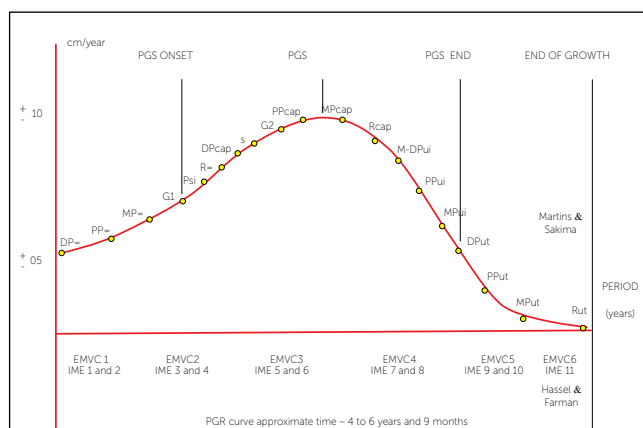


Figure 3 - Schematic location of Hassel and Farman's¹⁷ stages in the PGS curve.

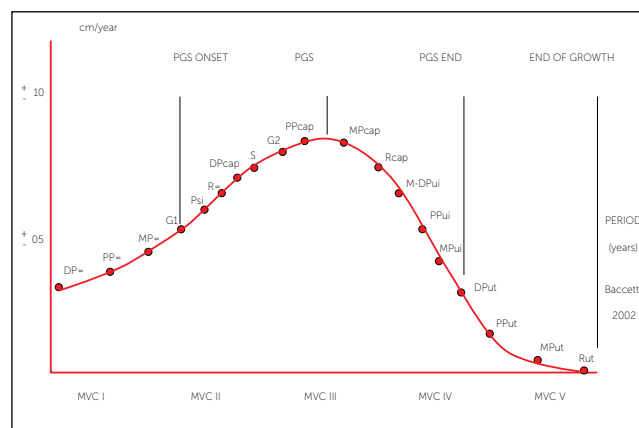


Figure 4 - Transposing the stages by Baccetti, Franchi and McNamara Jr³ into Martins and Sakima's PGS curve.

Kappa agreement index was used to assess the agreement between methods, a nonparametric test. Significance level was set at 5%.

RESULTS

Tables 1 to 3 show the results of the agreement analyses. These analyses were carried out between measurements taken at two different times (T_1 and T_2) with a view to assessing skeletal maturation in relation to Hassel and Farman's,¹⁷ Baccetti, Franchi and McNamara Jr's³ as well as Martins and Sakima's²³ methods, respectively. Tables 1 to 3 also show that the three methods studied herein present a statistically significant correlation ($P < 0.05$) between T_1 and T_2 , thus indicating excellent level of agreement between measurements (Kappa > 0.75). Therefore, satisfactory calibration was obtained for the classification criteria applied to the measures of each method.

Table 1 - Error of the method assessed by means of agreement analysis for evaluation of skeletal maturation by Hassel and Farman's method.¹⁷

		T_2			
T_1		A	B	C	D
Total		02	10	11	13
	Total	02	10	11	13

Kappa agreement index = 0.76 ($P < 0.0001$).

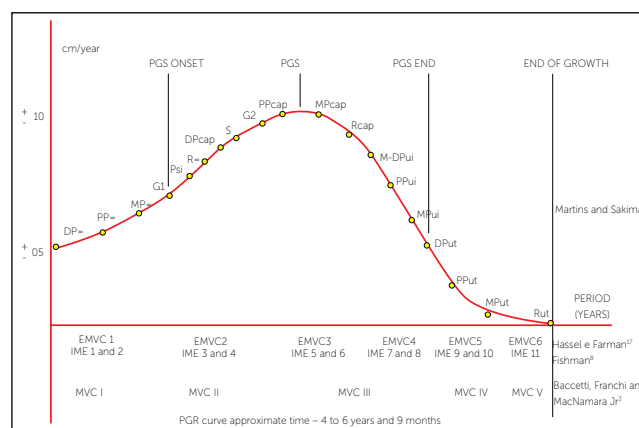


Figure 5 - Transposing the methods in the PGS curve.
 Stage A - When the individual is at DP=, PP= or MP=.
 Stage B - When the individual is at G1, Psi, R=, DPcap, S or G2.
 Stage C - When the individual is at PPcap, MPcap, Rcap, M-DPui, MPui or DPui.
 Stage D - When the individual is at PPut or MPut.
 Stage E - When the individual is at Rut.

Table 2 - Error of the method assessed by means of agreement analysis for evaluation of skeletal maturation by Baccetti, Franchi and McNamara Jr's method.³

		T_2			
T_1		A	B	C	D
Total		02	10	12	12
	Total	02	10	12	12

Kappa agreement index = 0.84 ($P < 0.0001$).

Table 3 - Error of the method assessed by means of agreement analysis for evaluation of skeletal maturation by Martins and Sakima's method.²³

		T_2											
T_1		DP	PP	MP	Psi	R	S	MPcap	M-DPui	MPui	DPut	PPut	MPut
Total		2	1	2	1	2	3	2	1	2	3	2	12
	Total	2	1	2	1	2	3	2	1	2	3	2	12

Kappa agreement index = 0.80 ($P < 0.0001$).

Table 4 - Agreement analysis between the methods by Hassel and Farman,¹⁷ and Baccetti, Franchi and McNamara Jr³ for evaluation of skeletal maturation.

Baccetti, Franchi and Macnamara Jr ³						
Hassel and Farman ¹⁷	A	B	C	D	E	Total
Total	02	10	11	13	0	36

Kappa agreement index = 0.80 (P < 0.0001).

Table 5 - Agreement analysis between the methods by Hassel and Farman,¹⁷ and Martins and Sakima²³ for evaluation of skeletal maturation.

Martins and Sakima ²³						
Hassel and Farman ¹⁷	A	B	C	D	E	Total
Total	05	08	07	13	03	36

Kappa agreement index = 0.77 (p < 0.0001).

Table 6 - Agreement analysis between the methods by Baccetti, Franchi and McNamara Jr,³ and Martins and Sakima²³ for evaluation of skeletal maturation.

Martins and Sakima ²³						
Baccetti, Franchi and MacNamara ³	A	B	C	D	E	Total
Total	05	08	07	13	03	36

Kappa agreement index = 0.81 (P < 0.0001).

Table 7 - Agreement analysis between the methods by Hassel and Farman,¹⁷ Baccetti, Franchi and McNamara Jr,³ and Martins and Sakima²³ compared all together for evaluation of skeletal maturation.

Response						
Individuals	A	B	C	D	E	Total
Total	9	28	30	38	3	108

Kappa agreement index = 0.63 (P < 0.0001).

The blue diagonal line highlighted in Tables 1 to 3 refers to cases in which both measurements agree.

Tables 4 to 6 show agreement of final results among the three methods of assessing skeletal maturation compared two by two. The data obtained show an excellent level of statistically significant (P < 0.05) agreement (Kappa > 0.75) between the methods by Hassel and Farman¹⁷ and Baccetti, Franchi and McNamara Jr,³ Hassel and Farman¹⁷ and Martins and Sakima,²³ and Baccetti, Franchi and McNamara Jr³ and Martins and Sakima.²³ Thus, the methods evaluated two by two are similar in terms of classification of skeletal maturation. The blue diagonal line highlighted in Tables 4 to 6 refers to cases in which both methods agree.

Table 7 shows that there is a statistically significant correlation that ranges from reasonable to good (0.40 < Kappa < 0.75) when the three methods used to assess skeletal maturation are compared all together.

DISCUSSION

The process of skeletal maturation is directly related to height, speed and specific amounts of craniofacial growth; however, no pattern can be established on the basis of simple chronology, only. Every individual undergoes a particular sequence of events and, for this reason, generalizing the descriptions of maturation stages associating them with the skeletal growth curve determined for the population as a whole can lead to error. Therefore, the concept of "normal skeletal age" should be questioned and the individuality of diagnosis should be valued.⁹

Several parameters are employed to predict the stage in which an individual is on the growth curve, namely: Chronological, dental and circumpubertal ages, which not only consider the emergence of secondary sexual and skeletal characteristics, but also the height-weight ratio. Since an individual's chronological age is not reliable to determine the beginning and end of facial growth, the skeletal age should be determined to define the individual's stage of biological growth, given that it proves to be the most reliable parameter for biological evaluation.^{6,20,27,29}

Skeletal maturation is influenced by constitutional-genetic, hormonal, nutritional, socioeconomic, climatic, seasonal, as well as biochemical-pharmacological factors, which may delay or speed up due to the presence of several diseases. Down's syndrome is among the most frequent causes of skeletal age retardation.

The pattern of skeletal maturation in individuals with DS has been widely investigated because the reports on the skeletal age of these individuals are controversial.^{4,15,18} According to Marcondes,²² the concept of bone age does not apply to newborns (non-carriers of chromosome 21 trisomy), given that the first carpal core is only observed after the third month. This finding confronts the studies by Hall,¹⁶ which claims to be possible to determine bone age at this stage of life by means of the ossification centers of individuals with DS.

According to the literature, the stage of maturation is influenced by factors such as sex, race, ethnic groups, among others. Bone development and growth were reported by Prates, Peters and Lopes²⁴ as well as Guzzi and

Carvalho¹⁴ who assessed skeletal maturation using the method by Greulich and Pyle.¹³ The authors observed that in non-syndromic females individuals aged between 13 and 14 years, as well as between 9 and 16 years old, respectively, an index of accelerated maturation was found.

As for male patients, Guzzi and Carvalho¹⁴ found skeletal maturation retardation in non-syndromic individuals, which was also observed by Aguiar¹ as well as Sannomiya and Calles.²⁶ who compared non-syndromic patients with individuals with Down's syndrome aged between 5 and 19 years old. Furthermore, it should be emphasized that the method proposed by Eklöf and Ringertz⁷ was not considered reliable to assess skeletal maturation in this population.

An individual's chronological moment may be used to determine one's bone age, provided that certain parameters be respected.¹² Franchi, Baccetti and McNamara Jr¹⁰ observed a significant decrease between stages 4 and 5³ after the end of pubertal growth. They further highlighted that this is a reliable method in the assessment of skeletal maturation. Canali, Brücker and Lima⁵ as well as Generoso et al¹² reported potential direct relationship between chronological age and CVM; however, skeletal maturation in female patients occurs earlier (about 1 year).

The preference and choice regarding the different methods are based on the experience and technical training of each professional. In addition, the reliability of the method consists of its ability to be compared, which is verified by intra-observer testing; as well as its reproducibility, observed by inter-observer assessment. In this study, the method proposed by Martins and Sakima²³ was used for hand and wrist radiographs, based on centers of ossification, whereas the methods of Hassel and Farman¹⁷ as well as Baccetti, Franchi and McNamara Jr³ were used for lateral cephalometric radiographs.

Radiographs were assessed and skeletal maturity stages were determined by a single observer, properly calibrated. Initially, the error of the method was observed at two different times (T_1 and T_2), based on the analysis of new scores attributed to the hand and wrist radiographs and the lateral cephalometric radiographs, as shown in Tables 1 to 3. Table 1 shows agreement in bone assessment using the method by Hassel and Farman,¹⁷ with Kappa index statistically significant ($p < 0.05$), thus indicating excellent level of agreement between measurements (Kappa > 0.75).

Excellent level of agreement was also observed for the methods by Martins and Sakima²³ as well as Baccetti, Franchi and McNamara Jr³ of which values are presented in Tables 2 and 3, respectively. Therefore, satisfactory calibration was obtained for the classification criteria applied to the measures of each method. Intra-observer assessment revealed that the scores attributed to the methods by Martins and Sakima²³ as well as Hassel and Farman¹⁷ agreed in 30 out of 36 subjects (83.3 %); whereas for Baccetti, Franchi and McNamara Jr³ there was an agreement of 32 out of 36 subjects (88.8 %). This percentage difference in favor of the latter may be due to greater assimilation of the operator, perhaps because it is a method of classification with fewer steps and, therefore, less subjective.

The results obtained from the lateral cephalometric radiographs analyzed by the method proposed by Hassel and Farman,¹⁷ as reported by Santos and Almeida,³⁰ Canali, Brücker and Lima⁵ as well as Santos et al,²⁹ showed a positive and significant correlation, thus indicating that the scores attributed to each one of them were similar.

Table 2 shows a positive and significant correlation for the comparison between T_1 and T_2 , which agrees with the two observers used in the study by Baccetti, Franchi and McNamara Jr.³ The error of the method analysis proposed by Martins and Sakima²³ was performed by Iguma, Tavano and Carvalho²⁰ who found a high correlation when assessing the PGS. Their study also found excellent agreement as revealed by the Kappa index obtained for the sample studied.

Should, in fact, there be an association between the aforementioned methods and the hand and wrist as well as the cervical vertebrae, this means that it would be possible to choose one of them to assess patient's skeletal maturation for routine orthodontic records. To elucidate a possible correlation between the methods proposed in this study, an agreement analysis of the final results was conducted by comparing the methods two by two.

The data obtained showed that the level of agreement between the methods by Hassel and Farman¹⁷ and Baccetti, Franchi and McNamara Jr³ (Table 4); Hassel and Farman¹⁷ and Martins and Sakima²³ (Table 5); as well as Baccetti, Franchi and McNamara Jr³ and Martins and Sakima²³ (Table 6) were statistically significant with excellent level of agreement

between them. Table 4 reveals that scores were concordant in 33 out of 36 subjects (91.6 %). Tables 5 and 6 reveal that 23 out of 36 subjects (63.8 %) and 25 out of 36 (69.4 %) were concordant, respectively. Data presented in Table 4 suggest that the lower the degree of subjectivity among the methods used, the higher the index of agreement, since both methods use inspection parameters based on the size and shape of the vertebrae.

The literature includes studies that report the use of agreement analysis between two different methods. Garcia¹¹ as well as Santos and Almeida³⁰ employed Fishman's⁸ methods for hand and wrist, whereas Hassel and Farman¹⁷ used it for cervical vertebrae and noted statistically significant correlation between them. San Román et al²⁸ confirm the previous results; however, the authors used the Grave and Brown method for hand and wrist.

It is observed that there is a difference regarding the choice of which method to use to assess hand and wrist as well as cervical vertebrae. However, regardless of the method studied, the results were similar, thus suggesting a correlation between maturation of vertebral bones and hand and wrist.

Table 7 shows a statistically significant correlation that ranges from reasonable to good ($0.40 < \text{Kappa} < 0.75$) among the three methods proposed to assess skeletal maturation when they were compared all together. Out of the 36 subjects assessed, 22 (61.1 %) achieved the same score for all three methods of bone maturation, whereas 14 (38.9 %) were not in agreement and 12 differed in only one stage with a difference of 1 score (the subject was "A" for a particular assessment method and "B" for another). One individual got different scores for all methods, and despite agreeing with the methods by Baccetti, Franchi and McNamara Jr³ as well as Hassel and Farman,¹⁷ one subject obtained a difference of two scores in relation to the method by Martins and Sakima.²³

According to Hassel and Farman,¹⁷ the 12 non-coincident results that varied in only one contiguous score have no clinical relevance to invalidate the method; and, for this reason, these results should be considered acceptable. Many dubious cases may not

allow a stage to be determined with precision, especially if one considers that the radiograph may have been obtained in a phase of transition from one stage to another subsequent. Thus, the examiner can classify the individual both in the beginning of a certain stage or in the end of another. We also emphasize that if these 12 individuals were considered acceptable, we would obtain an excellent Kappa agreement index.

One of the most important factors in assessing the stage of maturation by means of hand and wrist as well as lateral cephalometric radiographs was the presence of 19 ossification centers used to place the individual in the PGS curve by means of the method advocated by Martin and Sakima,²³ when compared to the methods by Baccetti, Franchi and McNamara Jr³ (five stages) as well as Hassel and Farman¹⁷ (six stages). For this reason, the method by Martins and Sakima²³ proves more subjective, given the difference in scores observed in 10 out of 12 non-concordant individuals for the three methods of the sample.

CONCLUSIONS

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

- » Adapting the methods developed by Martins and Sakima²³ to assess skeletal maturation by cervical vertebrae in the curve of PGS is a practical and useful tool in determining the stage of growth and development of individuals.

- » Stages of maturation assessed by cervical vertebrae and ossification centers observed in radiographs of the hand and wrist were considered reliable.

- » The data obtained revealed an excellent level of agreement between the methods by Hassel and Farman¹⁷ and Baccetti, Franchi and McNamara Jr,³ Hassel and Farman¹⁷ and Martins and Sakima,²³ as well as Baccetti, Franchi and McNamara Jr³ and Martins and Sakima,²³ all of which were statistically significant;

- » A statistically significant correlation that ranged from reasonable to good was obtained among the three methods used to assess skeletal maturation when they were compared all together.

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In vitro cytotoxicity of self-curing acrylic resins of different colors

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Objective: The aim of this study was to assess the *in vitro* cytotoxicity of acrylic resins of different colors over time.

Methods: Specimens were divided into 4 groups (n = 6) according to the color of the acrylic resin (Orto Class, Clássico, Campinas, São Paulo, Brazil): Group 1: clear acrylic resin; group 2: pink acrylic resin; group 3: blue acrylic resin and group 4: green acrylic resin. All specimens were fabricated according to the mass manipulation technique and submitted to mechanical polishing protocol. The control was performed with an amalgam specimen (C+), a glass specimen (C-) and cell control (CC). Specimens were immersed in Minimum Eagle's Medium (MEM) and incubated for 24 h at 37°C. The extracts from the experimental material were filtered and mixed with L929 fibroblast. Cytotoxicity was evaluated at 4 different times, 24, 48, 72 and 168 h. After contact, cells were incubated for 24 h and added to 100 µl of 0.01% neutral red dye. The cells were incubated for 3 h for pigment incorporation and fixed. Cells viability was determined by a spectroscopic (BioTek, Winooski, Vermont, USA) with a 492-nm wavelength $\lambda=492$ nm).

Results: There were no statistical differences between the experimental groups and the CC and C- groups.

Conclusion: Clear, pink, blue and green self-curing acrylic resins fabricated by means of the mass manipulation technique and mechanically polished are not cytotoxic. Neither the pigment added to the self-curing acrylic resin nor the factor of time influenced the cytotoxicity of the material.

Keywords: Acrylic resins. Cell culture techniques. Cytotoxins.

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INTRODUCTION

Chemically activated acrylic resins are widely used in the fabrication of fixed, removable and retention orthodontic appliances.⁴ Resin is sold in two vials: one containing the powder, the polymer, and the other containing the liquid, the monomer. The monomer is a clear, flammable and volatile liquid at room temperature.¹ It is considered cytotoxic and possibly genotoxic.^{9,10,22,23,24} The polymer usually has the pigment that gives color to the resin.

Adding the monomer (methyl methacrylate, MMA) to the polymer causes a resin polymerization reaction that occurs without the formation of by-products. Nevertheless, conversion of monomer into polymer is generally not complete,⁴ for this reason, some amount of monomer, known as residual,² remains. According to some studies, residual monomer remains in the manufactured orthodontic appliances, which indicates that varying amounts of residual monomer may be released into the oral cavity during the use of these appliances.^{4,10}

The residual monomer of methyl methacrylate not only changes the final physical properties of resins,^{3,12} but also induces the onset of systemic and local tissue reactions when in contact with saliva and soft tissues,^{8,9,11,17} thus causing hypersensitivity, lip swelling, chronic urticaria and sialorrhea.^{5,6} Furthermore, the pigment added to the powder may be another causative factor of hypersensitivity.

Although the *in vitro* cytotoxicity of MMA has already been demonstrated, no studies were conducted to assess the influence of pigments present in colored acrylics on cell viability. Thus, the aim of this study was to evaluate the *in vitro* cytotoxicity of acrylic resin at different periods and compare the cytotoxicity of acrylic resins of different colors.

MATERIAL AND METHODS

Preparation of specimens

For preparation of specimens, a metal matrix (10 mm X 5 mm X 2 mm) was molded with addition silicone (Express®, 3M/ESPE, St. Paul, USA) and the mold filled with self-curing acrylic resin (Ortho Class®, Classic, Campinas, São Paulo, Brazil). Powder-liquid ratio was obtained according to the manufacturer's instructions.

Each acrylic resin used for preparation of specimens was manipulated by means of the mass technique in

a dappen dish with a lid where the monomer was inserted immediately before the polymer was poured until its saturation. Subsequently, the dish was covered with the lid, which allowed the resin to go through a sandy and fibrillar phase until it reached its plastic phase during which it was inserted into the mold. The acrylic resin was processed in a resin polymerizer M-1000® (EDG Equipment and Control Ltda.) at 20°C and pressure of 25 psi (1.75 kg/cm²) for a period of 15 minutes.

After polymerization, mechanical polishing was carried out in a vise using a bristle brush with a mixture pumice and water for 1 minute, followed by felt with white paste of Spain used for 1 minute.

Groups

Four self-curing acrylic resins of different colors were divided into four groups as follows (n = 3): Group 1 (clear), 2 (pink), 3 (blue) and 4 (green).

Control

To assess cellular response against extremes, other three groups (n = 3) were included: Group CC (cell control), cells which were not exposed to any material. This group was used to monitor normal cell growth. Group C+ (positive control) consisting of specimen made of amalgam. Silver amalgam was used because of its well known cytotoxic ability.¹⁸ Specimens of 10 mm x 5 mm x 2 mm were manufactured in amalgamator (SDI®, Bayswater, Australia) and polished with abrasive rubber tips. Group C- (negative control) consisting of glass specimen. Glass was the material of choice for not triggering cytotoxicity effect.¹⁹

Cell culture

Cell lineage used was L929 obtained from the American Type Culture Collection (ATCC, Rockville, MD) (mouse fibroblasts) grown in Eagle's minimum essential medium (MEM) (Cultilab, Campinas, São Paulo, Brazil), supplemented with 2 mM L-glutamine (Sigma, St. Louis, Missouri, USA) 50 µg/mL gentamycin (Schering Plough, Kenilworth, New Jersey, USA), 2.5 µg/mL fungizone (Bristol-Myers-Squibb, New York, USA), 0.25 mL sodium bicarbonate solution (Merck, Darmstadt, Germany), 10 mM HEPES (Sigma, St. Louis, Missouri, USA) and 10 % fetal bovine serum (FBS) (Cultilab, Campinas, São Paulo, Brazil). It was kept at 37°C in an environment supplemented with 5 % CO₂.

Cytotoxicity assay

Acrylic resin, silver amalgam and glass specimens were sterilized by exposure to UV light (Labconco, Kansas, Missouri, USA) for 1 hour.¹⁹ Then, three samples of each material were placed in 24-well plates containing culture medium (MEM) (Cultilab, Campinas, São Paulo, Brazil). Supernatants were collected according to the time of evaluation, 24, 48, 72 and 168 hours (7 days), being the culture medium renewed every 24 hours.

Supernatants were placed, in triplicate, in 96-well plates containing confluent monolayer of L929 cells and incubated for 24 hours at 37°C in an environment containing 5 % CO₂. After incubation, the effect on cell viability was determined by means of the dye-uptake technique, as described by Neyndorff et al,¹⁶ but with minor modifications. The technique consists in adding 100 µL of 0.01 % neutral red (Sigma, St. Louis, Missouri, USA) into culture medium and incubation at 37°C for 3 hours for penetration of the dye in living cells.

After this period, the dye was discarded and the cells fixed for 5 minutes by adding 100 µL of formaldehyde solution (Reagen, Rio de Janeiro, Rio de Janeiro, Brazil) to 4 % in PBS (130 mM NaCl, 2 mM KCl; 6 mM Na₂HPO₄·2H₂O, 1 mM K₂HPO₄, pH 7.2). Subsequently, the dye was extracted by adding 100 µL of a solution of 1 % acetic acid (Vetec, Rio de Janeiro, Rio de Janeiro, Brazil) and 50 % methanol (Reagen, Rio de Janeiro, Rio de Janeiro, Brazil). After 20 minutes, a spectrophotometer (BioTek, Winooski, Vermont, USA) at a wavelength of 492 nm ($\lambda = 492 \text{ nm}$) was used to read the data.

Statistical analysis

Statistical analysis was performed with the SPSS 13.0 software (SPSS Inc., Chicago, Illinois, USA). Initially, data were submitted to Kolmogorov Smirnov and Levene's test to determine normality and homogeneity, respectively. The values of the amount of viable cells were subjected to analysis of variance (ANOVA), with two factors (color and time) to determine whether there were statistical differences between groups, and subsequently to Tukey's test (Table 1). Significance level was set at 5 %.

RESULTS

Results revealed increased cell viability from 24 to 48 h, a reduction in cell viability after 72 h and, an increase in cell viability after 168 h; however, with no statistically significant differences ($P \geq 0.05$).

The color of resin proved not to influence material cytotoxicity, since there were no differences between groups 1, 2, 3 and 4 at all times ($P \geq 0.05$).

At all times, the values of cell viability were statistically similar between clear acrylic resin (group 1) and blue acrylic resin (group 3), as well as between groups C- and CC ($P \geq 0.05$), thus proving the absence of cytotoxic effect of acrylic resin to fibroblasts. However, experimental group 2 (pink acrylic resin) and 4 (green acrylic resin) showed significant differences in comparison to group CC ($P < 0.05$) after 24 h, thus indicating a difference in normal cell growth. Group C+ showed statistical difference in comparison to all other groups at all time periods studied, thus showing a decrease in the number of viable cells.

Table 1 - Mean and standard deviation of the amount of viable cells and statistical analysis of evaluated groups.

Groups	24 h		48 h		72 h		168 h	
	Mean $\pm$ SD	St.	Mean $\pm$ SD	St.	Mean $\pm$ SD	St.	Mean $\pm$ SD	St.
1	690 $\pm$ 139.7	AC	1061 $\pm$ 76.25	A	854.3 $\pm$ 65.4	A	1213.1 $\pm$ 190.3	A
2	584.6 $\pm$ 81.1	A	1099.3 $\pm$ 116.4	A	876.6 $\pm$ 59.6	A	1281.1 $\pm$ 92.89	A
3	679.6 $\pm$ 117.8	AC	1137.2 $\pm$ 70.74	A	828.6 $\pm$ 134.3	A	1147.7 $\pm$ 91.53	A
4	583.3 $\pm$ 57.8	A	1143.2 $\pm$ 102.95	A	869.6 $\pm$ 72.36	A	1199.3 $\pm$ 102.3	A
C+	324.2 $\pm$ 25.4	B	550.6 $\pm$ 91.87	B	404 $\pm$ 59.4	B	580.7 $\pm$ 46.3	B
C-	708.4 $\pm$ 64.0	AC	1068.7 $\pm$ 178.7	A	918.6 $\pm$ 34.0	A	1228.2 $\pm$ 137.2	A
CC	730.6 $\pm$ 84.8	C	1108.4 $\pm$ 45.94	A	942.6 $\pm$ 49.14	A	1292.8 $\pm$ 143.9	A

Mean: mean values of the amount of viable cells;

SD: Standard deviation;

St: Statistics. Same letters account for the absence of statistical difference for Tukey's test ($p < 0.05$).

DISCUSSION

Acrylic resins are widely used in Dentistry; however, some studies have demonstrated that this material can cause allergic reactions.^{13,14,15} Nevertheless, most researches assessed material used for prosthetic purposes, most of which are heat-curing

Self-curing acrylic resins are the most frequently used in Orthodontics. According to Hensten-Pettersen and Wictorin,⁷ polymerization influences cytotoxicity. Their studies revealed lower cell growth in self-curing resins in comparison to heat-curing ones, and for both, cell growth was lower than in the control group.

Baker et al² found that residual monomer concentration was four times higher in saliva adjacent to the palatal surface of appliances manufactured with acrylic resin in comparison to total saliva, thus indicating the importance of assessing cytotoxicity of this material, as well as the effects produced by the pigment and by the time of exposure on material cytotoxic potential.

Acrylic resin color proved not to affect cell viability, thus suggesting that the pigment does not influence cytotoxicity levels. However, when specimens were made of pink and green acrylic resin, normal cell growth was modified, as shown by experimental groups 2 and 4 which differed from CC. Thus, toxic reaction seems not to be associated with neither pigment nor the other substances that constitute the polymer, but with increase in the level of residual monomer present in the material.⁶

In this study, groups 1, 2, 3 and 4 showed no statistically significant differences over time ($P \leq 0.05$), thus indicating that cytotoxicity was not affected within the times tested. This finding is in disagreement with Gonçalves et al⁶ who assessed cytotoxicity of acrylic resins for orthodontic purposes within 24 and 48 hours. Their results showed that there was less cell viability after 24 hours. This difference can be explained by the cell type used, given that Gonçalves et al⁶ used epithelial cells and not fibroblasts. Polishing may also be considered as,

according to Rocha Filho et al²⁰ and Gonçalves et al,⁴ it alters the level of residual monomer present in the acrylic resins. Release of residual monomer is responsible for the reduction in cell viability, and this release is more intense within the first 24 h.⁴ However, mechanical polishing decreases the levels of residual monomer⁶. For this reason, it is suggested that the polishing procedure performed in this study was key not to trigger toxic reaction.

Although there was no significant difference between the times of assessment, in all experimental groups, from 48 to 72 hours there was a decrease in the number of viable cells. The fact that release of residual monomer is considered crucial in determining cell viability corroborates the results by Rocha Filho et al.²⁰ In the graphs of this study, the authors demonstrate increased concentration of residual monomer from 2 to 5 days.

It is recommended that acrylic resin used to manufacture orthodontic appliances be properly proportioned and manipulated, following the manufacturer's recommendations to ensure safety for patients' health. Some measures may be taken to reduce the amount of residual monomer, such as: polymerization in water or under pressure, the use of correct monomer : polymer proportion, and storage in water for 72 hours after polymerization.^{2,17,21} Moreover, the different colors of resin tested can be used without causing any damage to the biocompatibility of the material.

CONCLUSION

According to the methodology used and the conditions established in this research, it can be concluded that:

- 1) Acrylic resin manufactured by means of the mass technique, polymerized under pressure and mechanically polished does not alter cell viability.
- 2) Color of acrylic resin has no effect on cell viability.
- 3) Cell viability is maintained when exposed to self-curing acrylic resin.

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Three-dimensional dental arch changes of patients submitted to orthodontic-surgical treatment for correction of Class II malocclusion

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Introduction: This study assessed the three-dimensional changes in the dental arch of patients submitted to orthodontic-surgical treatment for correction of Class II malocclusions at three different periods.

Methods: Landmarks previously identified on upper and lower dental casts were digitized on a three-dimensional digitizer MicroScribe-3DX and stored in Excel worksheets in order to assess the width, length and depth of patient's dental arches.

Results: During orthodontic preparation, the maxillary and mandibular transverse dimensions measured at the premolar regions were increased and maintained throughout the follow-up period. Inter canine width was increased only in the upper arch during orthodontic preparation. Maxillary arch length was reduced during orthodontic finalization, only. Upper and lower arch depths were stable in the study periods. Differences between centroid and gingival changes suggested that upper and lower arch premolars buccally proclined during the pre-surgical period.

Conclusions: Maxillary and mandibular dental arches presented transverse expansion at premolar regions during pre-operative orthodontic preparation, with a tendency towards buccal tipping. The transverse dimensions were not altered after surgery. No sagittal or vertical changes were observed during the follow-up periods.

Keywords: Orthodontics. Orthognathic surgery. Malocclusion. Dental models.

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INTRODUCTION

An increasing number of adult patients seek orthodontic treatment not only for esthetic reasons, but also due to recent improvements in socioeconomic conditions. This new perspective raised the need to investigate skeletal and dental changes in soft tissue morphology occurring in adult individuals, considering the increasing search for orthodontic and orthognathic treatment.¹

Knowledge on these changes in adulthood may help to determine if changes observed after orthodontic treatment occur primarily due to orthodontic relapse or are part of the natural process of development and maturation.²

Harris³ highlighted that changes in shape and size of the craniofacial dentoskeletal complex do not cease with biological maturity. Adulthood does not necessarily correspond to a period of absence of growth; even though change rates are lower and growth directions may be different than observed in children and adolescents. Therefore, changes occur, especially in the long term.

Long-term studies assessed the postoperative changes of orthodontically treated cases. In general, there is a tendency towards continuous reduction in the width and length of dental arches, with increase in crowding, overbite and overjet. The greatest problem has been the inability to determine whether these changes occur primarily as a result of orthodontic treatment, or if they are part of the natural maturation process.⁴

The stability of surgical changes in transverse dimensions has not been extensively assessed. Few specific studies^{5,6} investigated the stability of dental arches. Moreover, these few studies have important limitations because they do not describe the surgical technique employed and do not differentiate orthodontic relapse (dental) from surgical relapse (skeletal). An investigation with good methodology was conducted by Martin⁷ to assess the three-dimensional changes occurring in the maxillary dental arch of patients submitted to segmented osteotomy in a long-term follow-up.

In this context, this study aims at assessing the three-dimensional changes occurring in the dental arch morphology of patients submitted to orthognathic surgery for correction of skeletal Class II malocclusions.

MATERIAL AND METHODS

This retrospective study was conducted with 15 patients (10 females and 5 males) with skeletal Class II division 1 malocclusion (Table 1) whose files were obtained from the Center for Research and Treatment of Orofacial Deformities (CEDEFACE, Araraquara, São Paulo, Brazil) and a private maxillofacial surgery practice. Dental casts were obtained at three periods: (T_1) initial, (T_2) immediate preoperative (1 to 15 days before surgery) and (T_3) postoperative (minimum 6 months after the orthodontic appliance was removed). The following inclusion criteria were applied: 1) presence of all permanent teeth erupted and present in the dental arches at least from the maxillary right first molar to the maxillary left first molar; 2) dental casts with good conditions for analysis; 3) absence of anomalies of shape, incisal or occlusal abrasion, coronal fracture, caries or restorations requiring reconstruction during the study period; 4) absence of other craniofacial deformities, syndromes or cleft lip and palate; 5) preoperative and postoperative orthodontic treatment conducted without mechanical expansion or tooth extraction; 6) patients submitted to a single orthognathic surgery on one or both jaws; 7) patients older than 18 years old at surgery.

Patients comprising the sample were operated by means of the following surgical techniques: single-piece Le Fort I osteotomy combined with bilateral sagittal split mandibular osteotomy, or isolated bilateral sagittal split mandibular osteotomy.

The method employed in this retrospective study was similar to that described by Martin⁷ who used a three-dimensional digitizer MicroScribe-3DX (3D Digitizer – The Imaging Technology Group, Illinois, USA) for digitization of predetermined landmarks on the dental casts, following the method described by Moyers et al.⁸ The software was developed for digitization and automatic storage of captured coordinates by registry in X, Y and Z coordinates on the Excel software (Microsoft Windows – Excel 12.0 – Office 2007).

A total of 54 landmarks were identified on the maxillary arch and 52 on the mandibular arch (Fig 1) from second molar (when present) to the canines at both sides including: mid-distal, mid-buccal, mid-mesial, mid-palatal, and gingival, each individually identified for each tooth. A gingival landmark was also identified between central incisors, the most anterior

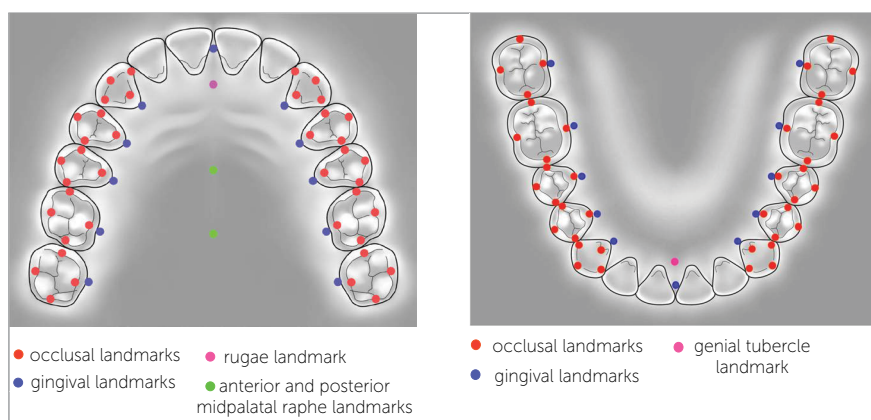


Figure 1 - Landmarks on the maxillary dental cast.

landmark in the dental arches (midline landmark = MP, Fig 1). Additional landmarks were also identified on the maxillary dental arch, namely: the rugae landmark (most posterior landmark on the incisive papilla), two landmarks on the palate (midpalatal raphe), being the first (anterior midpalatal raphe = AMR) between the first and second premolars and the second (posterior midpalatal raphe = PMR) at the mid-region of the first molar, following the position of the gingival landmark. On the mandibular dental arch, a mid-point was identified between the genial tubercles (a small rounded elevation on the lingual surface of the mandible on either side of the midline near the inferior border of the body of the mandible). The gingival landmark was identified on the most convex point of the gingival margin on the lingual aspect of each tooth. This process was repeated for each dental cast at different periods (T_1 , T_2 and T_3).

Dental casts were measured by a single examiner who was previously calibrated. Method error was assessed by intraclass correlation coefficient (ICC). For that purpose, all 15 triads of dental casts were digitized at two different periods, with a one-week interval.

At T_2 , for digitization of gingival landmarks obtained at the region of first and second molars (when present), the thickness of the band was subtracted, because this situation differs from T_1 and T_3 , when the patients were not wearing any fixed appliances. This was performed considering the mean thickness (0.20 mm) of bands of the main brands commercially available in Brazil (Abzil, Morelli).

All landmarks were digitized on each dental cast (T_1 , T_2 and T_3) and coordinates were stored in Excel worksheets specifically developed for that purpose.

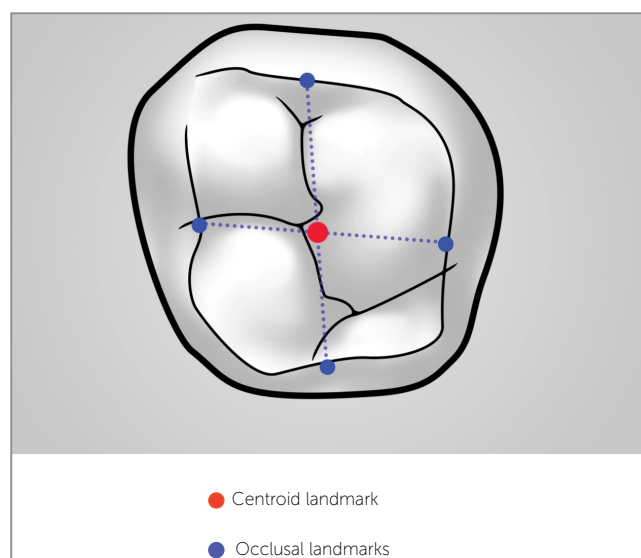


Figure 2 - Identification of the centroid landmark.

After identifying and recording all landmarks, the centroid landmarks were calculated for each tooth (Fig 2) using the values obtained on the X, Y and Z axis between the mid-distal and buccal-palatal landmarks, as described by Moyers et al.⁸ As a result, the process obtained measurements that are relatively independent from cusp wear and are sensitive to crown translation and tooth inclination.⁵

Transverse dimensions were calculated between canines (W3-3), first premolars (W4-4), second premolars (W5-5), first molars (W6-6) and second molars (W7-7) (when present) at both sides, both on the centroid landmarks (C) of crowns and on gingival margins (G) of teeth.

Arch depths were measured from the gingival landmark between central incisors perpendicular to a line connecting the centroids of canines (D33-RUGAE), premolars (D44-AMR) and first molars (D66-PMR)

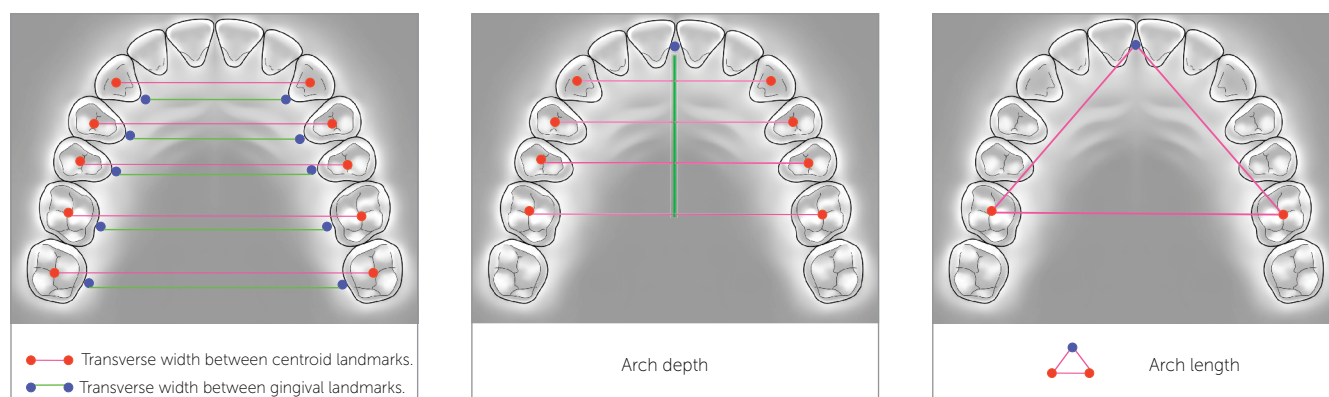


Figure 3 - Width (A), depth (B) and length (C) measurements on maxillary dental cast.

for the maxillary dental arch, and D66-MP for the mandibular dental arch. Values were calculated on a software developed on the Excel system which subtracted the distance between landmarks identified on the palate in relation to a constructed transverse line. Arch length (L66-MP) was measured from the gingival landmark between central incisors to the centroid landmark of first molar on both sides (Fig 3).

Differences in measurements between the study periods determined the three-dimensional changes occurring in the dental arches during preoperative orthodontic treatment (T_2-T_1) and after treatment completion (T_3-T_2). The total differences in treatment were also calculated, including the postoperative period (T_3-T_1).

Data were processed and analyzed on the statistical software SPSS version 15.0 (SPSS Inc, Chicago, IL, USA) for Microsoft Windows. The hypothesis of equality of means at the three periods for each variable was analyzed using the procedure general linear model – repeated measure.

RESULTS

The hypothesis was rejected when the p-value associated with the Hotteling-Lawley Trace was lower than 0.05. The means of variables for which this hypothesis was rejected when compared two by two by Bonferroni test for multiple comparisons of means. Test power is also presented for these variables. The correspondence of tooth movement (centroid) and skeletal movement (gingival) was compared by Student t-test for paired samples and Pearson correlation

coefficient. The sample comprised 10 females and 5 males with mean ages of 27.5 and 20.7 years, respectively, at treatment onset.

Mandibular arch

The transverse dimension between the centroid landmarks of second molars (W7-7) reduced in 0.58 mm after surgery (T_3-T_2). Differences among the measured widths in the centroid landmarks and measured widths in the gingival landmarks (W7-7C x W7-7G), indicative of buccal lingual inclinations, showed an increase of 0.65 mm during the pre-surgical phase (T_2-T_1) and a reduction of 0.54 mm in the post-surgical period (T_3-T_2), returning to the initial dimensions (T_3-T_1).

The difference in width between centroid and gingival landmarks (W6-6C x W6-6G) increased in 0.89 mm during the pre-surgical period (T_2-T_1) and reduced in 1.2 mm after surgery (T_3-T_2), returning to the initial values at the final evaluation, T_3-T_1 (Table 3).

The width between second premolars (W5-5) increased during orthodontic preparation (centroid: +1.69; gingival: +1.29), and remained stable from T_2 to T_3 (Table 2). The differences between centroid and gingival landmarks (W5-5C x W5-5G) increased in 0.4 mm during the pre-surgical period (T_2-T_1) (Table 3).

The width between first premolars (W4-4 C and G) showed similar results, as observed for second premolars at both study periods: T_2-T_1 centroid: +2.41; gingival: +1.81, T_3-T_2 : stable. The differences between centroid and gingival landmarks showed great values to centroid landmarks (0.59 mm) during the pre-surgical period (T_2-T_1) and remained stable after surgery, T_3-T_2 (Table 3).

Table 1 - Descriptive sample data.

Variable	Female (n = 10) Mean ± SD	Male (n = 5) Mean ± SD	Total (n = 15) Mean ± SD
Age / onset	27y 5m ± 8y 11m	20y 7m ± 3y 7m	25y 2m ± 8y 1m
Age / surgery	30y 0m ± 8y 11m	25y 7m ± 3y 9m	28y 6m ± 7y 9m
TOrtho	2y 7m ± 1y 5m	4y 12m ± 1y 9m	3y 5m ± 1y 10m
TSurg	1y 1m ± 0y 8m	2y 0m ± 0y 9m	1y 5m ± 0y 9m
Ttotal	3y 8m ± 2y 1m	6y 12m ± 2y 6m	4y 10m ± 2y 7m

Table 2 - Sample size (n), mean, standard deviation of changes between the two study periods, results of tests of equality of repeated measures means (means equals to zero) and multiple comparison of means. Mandibular arch.

Variable	n	T ₂ -T ₁	T ₃ -T ₂	T ₃ -T ₁	Hotteling-Lawley Trace			Test power
		Mean ± SD	Mean ± SD	Mean ± SD	F	DF	p-value	
W7-7C	12	0.78 ± 1.15	-0.58* ± 0.69	0.20 ± 1.16	5.05	2; 10	0.030	0.682
W7-7G	12	0.14 ± 1.09	-0.04 ± 0.84	0.10 ± 0.92	0.09	2; 10	0.911	
W6-6C	14	0.66 ± 1.39	-0.70 ± 1.28	-0.03 ± 1.46	2.41	2; 12	0.132	
W6-6G	14	-0.22 ± 1.01	0.50 ± 0.93	0.28 ± 0.79	2.13	2; 12	0.162	
W5-5C	15	1.69** ± 1.86	-0.47 ± 1.32	1.22* ± 1.69	5.84	2; 13	0.016	0.780
W5-5G	15	1.29* ± 1.59	-0.29 ± 0.96	1.00 ± 1.43	4.64	2; 13	0.030	0.676
W4-4C	15	2.41** ± 2.36	-0.37 ± 1.01	2.04** ± 2.08	7.38	2; 13	0.007	0.871
W4-4G	15	1.81* ± 2.10	-0.26 ± 0.89	1.56* ± 1.73	5.71	2; 13	0.017	0.770
W3-3C	15	0.23 ± 1.83	-0.15 ± 0.64	0.08 ± 1.94	0.51	2; 13	0.612	
W3-3G	15	0.57 ± 1.40	-0.11 ± 0.86	0.46 ± 1.69	1.34	2; 13	0.295	
L66-MP	14	0.85 ± 1.28	-0.34 ± 0.66	0.51 ± 1.14	3.22	2; 12	0.076	
D66-MP	14	0.67* ± 0.81	-0.16 ± 0.75	0.51 ± 1.14	4.73	2; 12	0.031	0.675

*, **, *** account for means of changes statistically different from zero with significance level set at 0.05; 0.01 and 0.001, respectively, detected by Bonferroni's test for multiple comparison of repeated measurements means.

Table 3 - Comparison of mean changes between centroid and gingival landmarks. Means and standard deviation of differences between changes, t-test for the hypothesis that changes are equal and correlation coefficient between changes. Mandibular arch.

Variables	Study period	Differences between changes			T-test	
		Mean ± SD	t	DF	p	r
W7-7C x W7-7G	T ₂ - T ₁	0.65 ± 0.72	3.10	11	0.010	0.79**
	T ₃ - T ₂	-0.54 ± 0.55	-3.43	11	0.006	0.76**
	T ₃ - T ₁	0.10 ± 0.82	0.44	11	0.671	0.72**
W6-6C x W6-6G	T ₂ - T ₁	0.89 ± 0.71	4.69	13	0.000	0.87***
	T ₃ - T ₂	-1.20 ± 0.98	-4.57	13	0.001	0.65*
	T ₃ - T ₁	-0.31 ± 0.95	-1.23	13	0.241	0.80***
W5-5C x W5-5G	T ₂ - T ₁	0.40 ± 0.45	3.44	14	0.004	0.98***
	T ₃ - T ₂	-0.18 ± 0.55	-1.24	14	0.235	0.93***
	T ₃ - T ₁	0.22 ± 0.59	1.45	14	0.168	0.94***
W4-4C x W4-4G	T ₂ - T ₁	0.59 ± 0.64	3.58	14	0.003	0.97***
	T ₃ - T ₂	-0.11 ± 0.57	-0.78	14	0.451	0.83***
	T ₃ - T ₁	0.48 ± 0.80	2.32	14	0.036	0.93***
W3-3C x W3-3G	T ₂ - T ₁	-0.34 ± 0.93	-1.43	14	0.175	0.87***
	T ₃ - T ₂	-0.04 ± 0.44	-0.36	14	0.725	0.87***
	T ₃ - T ₁	-0.38 ± 0.91	-1.64	14	0.123	0.88***

*, **, *** Statistically significant correlation coefficient with significance level set at 0.05; 0.01 and 0.001, respectively.

Dental arch length (L66-MP) and depth (D66-MP) were stable during the study periods, except for the depth assessed during orthodontic preparation which increased in 0.67 mm (Table 2).

Maxillary arch

W6-6G remained stable during orthodontic preparation and increased in 0.86 mm after surgery (T_3-T_2). Comparison between T_3-T_1 revealed an increase of 1.11 mm in W6-6C. The difference between centroid and gingival landmarks (W6-6C x W6-6G) increased in 1.18 mm during the pre-surgical period (T_2-T_1) (Table 5).

W5-5G (+0.96) and C (+2.51) distances increased during orthodontic preparation and remained stable from T_2 to T_3 (Table 4). Differences between centroid and gingival landmarks (W5-5C x W5-5G) increased in 1.54 mm during pre-surgical orthodontic preparation (T_2-T_1) (Table 5).

The same behavior was observed for W4-4 C (+3.29 mm) and W4-4 G (+2.25 mm) distances that increased during the pre-surgical period. Differences between centroid and gingival landmarks (W4-4C x W4-4G) increased in 1.04 mm during the pre-surgical period and remained stable after surgery.

At the region 3-3, there was an increase of 1.72 mm between centroids and 1.23 mm in the gingival landmark between T_1 and T_2 . Differences between centroid and gingival landmarks (W3-3C x W3-3G) decreased in 0.23 mm in the post-surgical period (Table 5).

Arch length (L66-MP) remained stable during orthodontic preparation (T_2-T_1) and reduced in -0.74 mm from T_2 to T_3 . Arch depth remained stable at all study periods (Table 4).

DISCUSSION

This study analyzed the three-dimensional changes occurring in the maxillary and mandibular dental arches of patients submitted to orthognathic surgery at two different periods: during preoperative orthodontic preparation and in the postoperative follow-up. The postoperative period included patients monitored for at least 6 months after the orthodontic appliance was removed with a mean period of postoperative evaluation of 1.1 years for females and 2 years for males (Table 1). Patients used retainers after removal of fixed appliances for an average period of 6 months. This period was adequate for assessing the most critical period of stability. No long-term

Table 4 - Sample size (n), mean, standard deviation of changes between the two study periods, results of tests of equality of repeated measures means (means equals to zero) and multiple comparison of means. Maxillary arch.

Variable	n	T_2-T_1	T_3-T_2	T_3-T_1	Hotteling-Lawley Trace			Test power
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	F	DF	p-value	
W7-7C	13	0.26 $\pm$ 1.60	0.20 $\pm$ 2.34	0.46 $\pm$ 1.72	0.59	2; 11	0.573	
W7-7G	13	-0.15 $\pm$ 1.65	0.31 $\pm$ 1.94	0.16 $\pm$ 1.40	0.16	2; 11	0.856	
W6-6C	15	0.52 $\pm$ 1.90	0.59 $\pm$ 1.32	1.11* $\pm$ 1.46	5.12	2; 13	0.023	0.721
W6-6G	15	-0.66 $\pm$ 1.56	0.86* $\pm$ 1.18	0.20 $\pm$ 0.82	4.74	2; 13	0.029	0.686
W5-5C	15	2.51** $\pm$ 2.19	0.11 $\pm$ 1.02	2.61*** $\pm$ 1.86	14.10	2; 13	0.001	0.991
W5-5G	15	0.96* $\pm$ 1.34	0.23 $\pm$ 1.02	1.20** $\pm$ 1.32	5.84	2; 13	0.016	0.780
W4-4C	15	3.29*** $\pm$ 2.50	-0.14 $\pm$ 1.29	3.15*** $\pm$ 2.28	13.75	2; 13	0.001	0.990
W4-4G	15	2.25*** $\pm$ 1.67	-0.18 $\pm$ 1.04	2.07*** $\pm$ 1.59	13.65	2; 13	0.001	0.990
W3-3C	15	1.72* $\pm$ 2.11	-0.52 $\pm$ 1.11	1.19 $\pm$ 2.04	4.95	2; 13	0.025	0.706
W3-3G	15	1.23* $\pm$ 1.48	-0.29 $\pm$ 1.02	0.94 $\pm$ 1.53	4.85	2; 13	0.027	0.697
L66-MP	15	-0.07 $\pm$ 2.25	-0.74** $\pm$ 0.80	-0.81 $\pm$ 2.14	6.69	2; 13	0.010	0.836
D33-RUGAE	15	-0.09 $\pm$ 0.83	-0.01 $\pm$ 0.39	-0.10 $\pm$ 0.81	0.11	2; 13	0.845	
D44-AMR	15	-0.12 $\pm$ 1.36	-0.54 $\pm$ 1.43	-0.66 $\pm$ 1.26	2.03	2; 13	0.171	
D66-PMR	15	-0.20 $\pm$ 0.65	0.26 $\pm$ 0.59	0.06 $\pm$ 0.72	1.53	2; 13	0.253	

*, **, *** Account for means of changes statistically different from zero with significance level set at 0.05; 0.01 and 0.001, respectively, detected by Bonferroni's test for multiple comparison of repeated measurements means.

Table 5 - Means and standard deviation of differences between centroid and gingival landmarks, means and standard deviation of differences of changes, t-test for the hypothesis that changes are equal and correlation coefficient between changes. Maxillary arch.

Variables	Difference between changes		T-test			
	Study period	Mean $\pm$ SD	t	DF	p	r
W7-7C x W7-7G	T ₂ - T ₁	0.41 $\pm$ 1.01	1.46	12	0.169	0.81***
	T ₃ - T ₂	-0.11 $\pm$ 0.58	-0.70	12	0.496	0.98***
	T ₃ - T ₁	0.30 $\pm$ 0.89	1.20	12	0.252	0.86***
W6-6C x W6-6G	T ₂ - T ₁	1.18 $\pm$ 0.77	5.93	14	0.000	0.92***
	T ₃ - T ₂	-0.27 $\pm$ 0.72	-1.45	14	0.169	0.84***
	T ₃ - T ₁	0.91 $\pm$ 0.81	4.35	14	0.001	0.90***
W5-5C x W5-5G	T ₂ - T ₁	1.54 $\pm$ 1.36	4.38	14	0.001	0.81***
	T ₃ - T ₂	-0.13 $\pm$ 0.71	-0.69	14	0.501	0.76**
	T ₃ - T ₁	1.42 $\pm$ 1.25	4.38	14	0.001	0.74**
W4-4C x W4-4G	T ₂ - T ₁	1.04 $\pm$ 1.20	3.36	14	0.005	0.91***
	T ₃ - T ₂	0.04 $\pm$ 0.76	0.18	14	0.857	0.80***
	T ₃ - T ₁	1.08 $\pm$ 1.00	4.18	14	0.001	0.93***
W3-3C x W3-3G	T ₂ - T ₁	0.49 $\pm$ 0.97	1.94	14	0.072	0.91***
	T ₃ - T ₂	-0.23 $\pm$ 0.34	-2.60	14	0.021	0.95***
	T ₃ - T ₁	0.25 $\pm$ 1.01	0.98	14	0.343	0.88***

*, **, *** Statistically significant correlation coefficient with significance level set at 0.05; 0.01 and 0.001, respectively.

evaluations were included to reduce the chance of influence from slight dental arches changes after growth completion, as described in the literature,^{2,3,9,10,11} since these changes were observed in 10-year to 34-year longitudinal studies.

Comparison with an untreated group would be valuable, since dimensional changes in the dental arches continue to occur even after post-pubertal growth.^{2,3,11,12,13} Description of changes that naturally occur in untreated individuals may be taken as gold standard to assess the changes caused by orthodontic treatment.¹³ The difficulty to achieve a paired group in terms of age, sex and type of malocclusion, as well as the ethical aspect concerning the impossibility to offer treatment during the study period (58 months) led to the decision to include a single group in this study.

Dimensional changes in the dental arches of untreated individuals are known, yet some divergences still persist among authors. Nevertheless, the described changes are of small magnitude (smaller than 1 mm) for a study period of 10 to 34 years, with a tendency towards narrowing and shortening of maxillary and mandibular dental arches over time. Bondevik¹⁴ reported different results, with changes slightly greater than 1 mm and in opposite direction of what was reported by other studies. In the present study, assessment was conducted for a mean period of 4 years and 10 months, which reduces the interference of

potential changes in the maturation of occlusion on the present results. However, dimensional changes smaller than 1 mm should be carefully considered to avoid confusion with occasional changes inherent to sample aging.

The methods employed in this study, which included the use of the three-dimensional digitizer MicroScribe-3DX, a tool with proven efficacy,¹⁵ allowed assessment of three-dimensional changes of dental arches and possible influences caused by orthodontic treatment and surgical therapy.

Sample size was calculated based on data available in the literature,⁷ and was used to assess the hypothesis that the mean changes of a measurement between two study periods would be equal to zero. That is to say, the hypothesis that treatment performed between the two periods did not cause any average changes at a maximum significance level of 5%, minimum power of 80%, and under the condition that the mean was different from zero for at least half standard deviation. In these conditions, the minimum sample size was established at 25 patients. During the study, we decided to separate patients with Class II and Class III malocclusions in order to allow better homogenization of the sample. This resulted in two groups of 15, one of each class of patients. Power at these new conditions was calculated to confirm that they did not significantly reduce the power of the tests employed (Tables 2 and 4).

The preoperative period (T_2-T_1) revealed the role orthodontic treatment plays to prepare the dental arches in order to achieve normal occlusion after surgery. In general, maxillary and mandibular dental arches exhibited similar features at this period (Tables 2 and 4). Inter-premolar widths were increased at this period (from 1.69 mm to 3.29 mm) and buccal tipping, demonstrated by differences between the centroid and gingival landmarks, was very important (Tables 3 and 5). A study with similar methodology⁷ revealed that, during orthodontic preparation, W4-4 (1.5 ± 2.0) and W5-5 (1.4 ± 2.0) measured by the centroid were expanded, revealing the clear orthodontic tendency towards eliminating the natural compensation established.

The idea that mandibular inter-canine width is basically unchangeable has been repeatedly supported in the literature. Burke et al¹⁶ assessed stability in the mandibular inter-canine width of cases orthodontically treated with and without extractions. Their results revealed that, regardless of diagnosis and type of treatment, mandibular inter-canine width presents a tendency towards expansion in 1 to 2 mm during treatment, returning to the initial dimensions after the retention period. Our results revealed that inter-canine width remained stable for the mandibular arch at the three study periods. Conversely, the maxillary arch increased in the orthodontic period (centroid 1.72 mm and gingival 1.23 mm) with stability in the postoperative period. Similar results were described by Martin⁷ who observed an increase in the maxillary W3-3 of 0.7 ± 2.1 from the centroid landmark, during the orthodontic period. Ward et al¹⁷ observed that, from 20 to 31 years of age, small increases occur in maxillary and mandibular intercanine widths ($+0.22$ and $+0.05$, respectively).

In the mandibular arch, the distance between second molars measured from the centroid landmark reduced during orthodontic finalization (T_3-T_2). Despite such reduction, measurements obtained between the centroid and gingival landmarks (Table 3) at T_2-T_1 revealed greater movement of the centroid landmark, with opposite movement at T_3-T_2 .

Martin⁷ observed that, during orthodontic preparation, W6-6 and W7-7 measured from the centroid landmark remained stable, differently from what was observed when measurement was performed from the gingival landmark, which revealed a reduction in W6-6 (-2.1 ± 3.0) and W7-7 (-1.6 ± 2.2). A possible explanation

for this finding might be related to the presence of bands at T_2 when measurements comparing the initial treatment period were obtained, thus impairing the correct identification of gingival landmarks and giving rise to smaller preoperative measurements. In the present study, 0.2 mm were decreased from T_2 measurement on each side of the arch in order to avoid this interference.

The use of preformed archwires may be related to an increase in inter-premolar width, since patients with Class II division 1 malocclusion often present triangular-shaped dental arches. The greater increase observed in the maxillary arch may be related to the need to coordinate maxillary and mandibular archwires in transverse direction, since the dental arches of patients with Class II relationship tend to present posterior cross-bite when changed to a Class I relationship at surgery. The surgeries performed did not include dentoalveolar segmentation so as to allow surgical correction of transverse discrepancies in three or four pieces. Even though this study did not include individuals treated with mechanical expansions, the coordination of archwires with the use of diagrams is very common during the preoperative period. Surprisingly, no transverse relapse was observed in the postoperative period (T_3-T_2). Considering that potentially unstable movements should be avoided during the preoperative orthodontic period,¹⁸ widening of dental arches in the transverse direction by expansion and buccal tipping may be an inadvisable procedure. However, the preoperative changes observed in the present study did not cause contraction of dental arches after removal of the orthodontic appliance. Conversely, solid transverse stability was observed both in the maxillary and mandibular arches. During T_3-T_1 , three out of four measurements in the mandibular arch indicating arch expansion at period T_2 remained positive and higher than what was observed at the onset of assessment at T_1 (Table 2). In the maxillary dental arch, four out of six measurements indicating transverse expansion observed in preoperative orthodontics were still increased by the end of the assessment period (Table 4).

The clinical application of these findings is very important. Transverse expansions during preoperative orthodontic treatment allow adequacy of dental arch dimensions and prevent the need for maxillary segmentation, commonly used for that purpose. This would reduce the period of surgical intervention and inherent morbidity of the additional procedure.

Moreover, expansion of dental arches favors the resolution of tooth crowding without affecting the incisors inclination.

These findings should be carefully interpreted. In the mandibular arch, except for first premolars, all measurements indicating inclination of posterior teeth at T_3 - T_1 , which compared the first and last evaluations of the present study, were non-significant, revealing that buccal tipping observed at T_2 was not present at T_3 (Table 3). In the maxillary dental arch, both transverse dimensions and buccal tipping of posterior teeth achieved by pre-operative orthodontic treatment presented a tendency towards maintenance at the final study period (Tables 4 and 5). The length and depth of maxillary and mandibular dental arches remained unchanged in the study periods. This may be assigned to transverse expansion of dental arches, which was maintained throughout treatment. The only exception observed was a slight

decrease (0.74 mm) in the length of the maxillary dental arch at the postoperative period (Table 4).

Future studies with longer follow-ups after the retention period, conducted with larger samples and with paired control groups, may contribute to confirm the present findings.

CONCLUSIONS

Maxillary and mandibular dental arches presented transverse expansion with buccal tipping of maxillary and mandibular premolars and maxillary canines during preoperative orthodontic preparation of patients with Class II division 1 malocclusion. This expansion remained throughout the study period. With regards to inclination of posterior teeth, the maxillary arch presented greater stability than the mandibular arch. Further studies are necessary to confirm the present findings.

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Lateral cephalometric diagnosis of asymmetry in Angle Class II subdivision compared to Class I and II

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Introduction: Lateral cephalometric radiographs are traditionally required for orthodontic treatment, yet rarely used to assess asymmetries.

Objective: The objective of the present study was to use lateral cephalometric radiographs to identify existing skeletal and dentoalveolar morphological alterations in Class II subdivision and to compare them with the existing morphology in Class I and II relationship.

Material and Methods: Ninety initial lateral cephalometric radiographs of male and female Brazilian children aged between 12 to 15 years old were randomly and proportionally divided into three groups: Group 1 (Class I), Group 2 (Class II) and Group 3 (Class II subdivision). Analysis of lateral cephalometric radiographs included angular measurements, horizontal linear measurements and two indexes of asymmetry that were prepared for this study.

Results: In accordance with an Index of Dental Asymmetry (IDA), greater mandibular dental asymmetry was identified in Group 3. An Index of Mandibular Asymmetry (IMA) revealed less skeletal and dental mandibular asymmetry in Group 2, greater skeletal mandibular asymmetry in Group 1, and greater mandibular dental asymmetry in Group 3.

Conclusion: Both IDA and IMA revealed greater mandibular dental asymmetry for Group 3 in comparison to Groups 1 and 2. These results are in accordance with those found by other diagnostic methods, showing that lateral cephalometric radiography is an acceptable method to identify existing skeletal and dentoalveolar morphological alterations in malocclusions.

Keywords: Facial asymmetry. Malocclusions. Radiography. Cephalometry.

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INTRODUCTION

Class II subdivision is characterized by an asymmetrical posterior occlusal relationship in which the dental arches demonstrate a Class I relationship on one side and a Class II relationship on the other side. This asymmetrical occlusal relationship is of skeletal and/or dentoalveolar origin.¹ Knowing the origin of this asymmetry is extremely important to ensure correct treatment of individuals with Class II subdivision.

Slight degrees of facial asymmetry are common among the general population.² Individuals with Class II subdivision typically present an accentuated degree of asymmetry that involves the lower third of the face and the mandible.^{3,4,5}

Alavi et al⁶ reported the distal position of the first lower molar as the main cause of Class II subdivision asymmetry. Additionally, these authors stated that asymmetry could have dentoalveolar or skeletal etiology. Rose et al⁷ also observed first lower molar in Class II subdivision asymmetry positioned more posteriorly on the Class II side; however, these authors stated that asymmetry resulted from dentoalveolar involvement without observable changes in the jaw. The position of dental midlines in relation to the facial midline was examined and revealed⁸ that lower dental midline deviation was more common than upper midline deviation, suggesting the cause of this asymmetry to be mandibular in nature.

While observing maxillary and mandibular changes in Class II subdivision and Class I malocclusions, Janson et al⁹ showed that dentoalveolar changes occurred in jaws without positional asymmetry. The main cause of Class II subdivision relationship was the distal position of lower molars on the Class II side. The position of upper mesial molars, also on the Class II side, was a secondary cause. The lower dental midline also presented more frequent deviations on the Class II side than the upper dental midline did. Therefore, this study⁹ as well as others^{4,7,8,10,11} demonstrated that asymmetries present in Class II subdivision patients are mainly of dentoalveolar origin.

Computed tomography is considered an optimal diagnostic method for asymmetry assessment,¹² but the cost of this method is higher and its radiation dose is greater in comparison to other methods. Photographs have been compared to posteroanterior radiographs, but no significant correlation has been found

between methods.¹³ Edler et al¹⁴ argued that photographs should be used simultaneously with posteroanterior radiographs. When photographs were compared to submentovertex radiographs and posteroanterior radiographs,¹⁵ a small correlation was found between methods. Posteroanterior radiographs allow observations of vertical and transversal changes; however, reports in the literature^{6-9,11,12} have noted a greater change in the anteroposterior positioning of molars in Class II subdivision malocclusion.

Although anteroposterior changes can be observed with submentovertex radiographs, Lew and Tay¹⁶ found a distortion in linear measurements taken with these radiographs. Additionally, Arnold et al¹⁷ reported difficulties in using submentovertex radiographs. The use of 45° cephalometric radiographs offers another method that allows visualization of structures in the anteroposterior direction, but this method is not routinely applied because it requires two further radiographic images in addition to those required for basic orthodontic documentation. Study models may be used for observation of dental structures in the anteroposterior direction, but these models do not allow skeletal observations. In addition, panoramic radiographs do not enable anteroposterior morphological alterations to be visualized.^{18,19}

Because they are traditionally required for orthodontic treatment, lateral cephalometric radiographs allow visualization of anteroposterior structures in a simple manner without additional costs to the orthodontist. Only one study⁶ has used lateral cephalometric radiographs to observe the position of molars and the existence of an asymmetrical mandibular relationship in the anteroposterior direction.

Therefore, the objectives of our study were to use lateral cephalometric radiographs to identify skeletal and dentoalveolar morphological alterations in cases of Class II subdivision; to compare these changes with morphology of Class I and Class II; and to assess the incidences of dental and skeletal symmetry and asymmetry of the maxilla and mandible.

MATERIAL AND METHODS

This research was approved by the School of Dentistry — State University of São Paulo Institutional Review Board. The sample comprised 90 male and female Brazilian children aged between 12 and 15 years old, randomly selected in the archives of the School of Dentistry,

State University of São Paulo/Araraquara. The sample was divided into three equal groups of Class I, Class II or Class II subdivision patients. Malocclusion criteria were based on the occlusal relationship between upper and lower arches obtained on study models and photographic documentation. Molar and canine relationships in Group 1 (Class I) were bilateral and symmetrical, whereas those in Group 2 (Class II) were displaced in more than half the width of a cusp. In Group 3 (Class II subdivision), molar and canine exhibited a Class I relationship on one side and a Class II relationship on the other side. Additional inclusion criteria for all groups were as follows: normal lower arch or a lower arch with slight lower-anterior crowding, and the presence of all permanent teeth in the dental arches (from first molar to first molar) with eminent eruption or eruption of second molars. Subjects were excluded if they had occlusal interferences that might cause functional alterations (e.g., dental crossbite, open bite or history of facial trauma).

Standardized lateral cephalometric radiographs were taken with patients' teeth in maximum habitual intercuspation with relaxed lips and face positioned with Camper's plane parallel to the ground. Radiographs were taken with Rotograph plus model MR05, adjusted for 85 Kvp, 10 mA and 0.5 seconds of exposure time. The equipment had fixed and constant focus-object distance of 1.5 meters. The chassis with Kodak™ - TMG/RA, 20.3cm x 25.4 cm film was positioned 15 cm away from the medial sagittal plan, giving an average magnification factor of 10%.

Cephalometric analysis was performed by digitizing twenty-one points identified in the lateral radiographs (Fig 1) by the same researcher using a Numonics Accu-Grid digitizer (TPL 1212 – Kurta, Seymour, Connecticut – USA) and Dentofacial Planner Plus, version 6.5, 1995 (Dentofacial software Inc. Toronto, Ontario – Canada). Radiographs were randomly digitized by means of simple random sampling without group identification.

For characterization of the sample, the following angular measurements were used: SNA, SNB, ANB, SNPP (angle formed by the SN line and the palatal plane [ANS – PNS]), SNOP (angle formed by the SN line and the occlusal plane [Op – Oa]), SN-GoMe, U1.SN, L1GoMe, U1.L1 and NAPog. Study analysis involved two indexes (i.e., the index of dental asymmetry and the index of mandibular asymmetry) as well as five linear measurements (RA-RP,

D7UA-D7UP, D6UA-D6UP, D7LA-D7LP and D6LA-D6LP) (Fig 2).

Index of dental asymmetry (IDA)

An IDA was developed based on the difference in distance between the most anterior and the most posterior molars in the upper and lower dental arches [$IDA1 = (D6UA - D6UP) - (D6LA - D6LP)$]. Similarly, this index was applied for second upper and lower molars [$IDA2 = (D7UA - D7UP) - (D7LA - D7LP)$].

Mathematically, a difference of zero represents upper-lower dental symmetry. A variation from normality of ± 0.5 mm was used for the tolerance criterion; this value corresponds to the degree of magnification between the right and left sides in cephalometric measurements. Values greater than 0.5 mm represented a greater distance between upper molars than between lower molars, and thus indicated upper dental asymmetry. Values of less than -0.5 mm represented a greater distance between lower molars than between upper molars, and thus indicated lower dental asymmetry.

For example, the IDA using the first molars is described as follows:

- » $IDA1 = (D6UA - D6UP) - (D6LA - D6LP)$, where
- » $(D6UA - D6UP)$ = distance between the most anterior image of the upper first molar (D6UA) and the most posterior molar (D6UP); and
- » $(D6LA - D6LP)$ = distance between the most anterior image of the lower first molar (D6LA) and the most posterior molar (D6LP).

If:

- » $IDA > 0.5$ mm = upper dental asymmetry;
- » $IDA < -0.5$ mm = lower dental asymmetry;
- » -0.5 mm $\geq IDA \leq 0.5$ mm = upper and lower dental symmetry.

Index of mandibular asymmetry (IMA)

Following the same logic, an IMA was developed based on the difference in distance between the most anterior and the most posterior portions of the mandibular ramus, and the distance between the most anterior and the most posterior lower first molars [$IMA1 = (RA - RP) - (D6LA - D6LP)$]. Similarly, this index was applied for second molars [$IMA2 = (RA - RP) - (D7LA - D7LP)$].

Mathematically, a difference of zero between skeletal and dental mandibular distances indicated dental

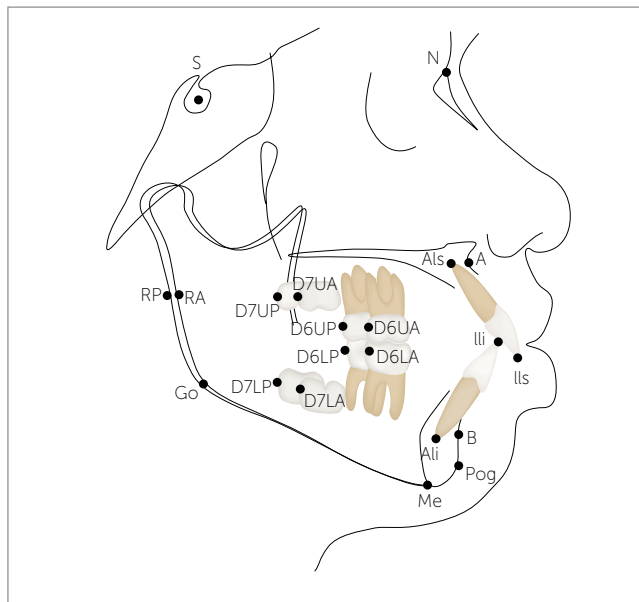


Figure 1 - Skeletal and dental cephalometric points. S (Sella), N (Nasion), A (Subspinal), B (Supramental), Go (Gonial), Me (Mentalis), Pog (Pogonion), Ili (Incisal edge of maxillary central incisor), Als (Apex of upper incisor), Ali (Apex of lower incisor), RA (Anterior ramus), RP (Posterior ramus), D7UA (Point in the distal face of the most anterior image of the second upper molar crown), D7UP (Point in the distal face of the most posterior image of the second upper molar crown), D6UA (Point in the distal face of the most anterior image of the first upper molar crown), D6UP (Point in the distal face of the most posterior image of the first upper molar crown), D7LA (Point in the distal face of the most anterior image of the second lower molar crown), D7LP (Point in the distal face of the most posterior image of the second lower molar crown), D6LA (Point in the distal face of the most anterior image of the first lower molar crown), D6LP (Point in the distal face of the most posterior image of the first lower molar crown).

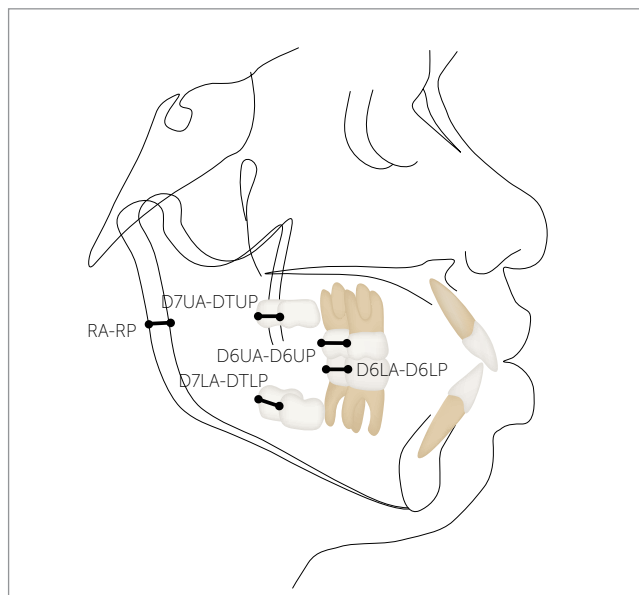


Figure 2 - Skeletal and dental linear cephalometric measurements. RA-RP (Horizontal distance between the anterior (RA) and posterior (RP) images of the posterior mandibular borders), D7UA-D7UP (Horizontal distance between the D7UA and D7UP points), D6UA-D6UP (Horizontal distance between the D6UA and D6UP points), D7LA-D7LP (Horizontal distance between the D7LA and D7LP points), D6LA-D6LP (Horizontal distance between the D6LA and D6LP points).

and skeletal mandibular symmetry. As above, a tolerance criterion of ± 0.5 mm was used to indicate variation from normality. Values greater than 0.5 mm represented skeletal asymmetry, as the anterior-posterior extent of the ramus was greater than that of the lower molars. On the other hand, values of less than -0.5 mm represented dental asymmetry, as the anterior-posterior extent of the lower molars was greater than that of the mandibular ramus.

For example, the IMA using the first molars was described as follows:

» $IMA1 = (RA - RP) - (D6LA - D6LP)$, where

» (RA-RP) = distance between the most anterior image of the mandibular ramus (RA) and the most posterior one (RP); and

» (D6LA-D6LP) = distance between the most anterior image of the lower first molar (D6LA) and the most posterior one (D6LP).

If:

» $IMA > 0.5$ = mandibular skeletal asymmetry;

» $IMA < -0.5$ = mandibular dental asymmetry;

» $-0.5 \text{ mm} \geq IMA \leq 0.5 \text{ mm}$ = skeletal and dental mandibular symmetry.

Statistical analysis

To assess consistency of measurements, six radiographs from each group were digitized twice by the same researcher with an interval of two weeks in between. The intra-class correlation coefficient (ICC) was used to assess reliability of the variable measurement process. Measurements were considered adequate when the ICC value was greater than 0.95.

To test the hypothesis that mean angular measurements were equivalent for the three groups, an analysis of variance (ANOVA) was used. When Levene's prior test rejected the hypothesis of homogeneity of variances, Brown-Forsythe test was used to verify equality of means. Scheffé's multiple comparison test was used to detect significant differences between groups.

A chi-square test was used to test the hypothesis that the proportion of subjects with asymmetries did not differ between groups, and to determine whether there was an association between category of asymmetry and group. A 95% confidence level ($p < 0.05$) was considered statistically significant. Statistical analyses were performed using SPSS software, version 16.0 for Windows (release 16.01 – Nov. 2007; SPSS Inc., 1989–2007).

RESULTS

Reliability of the method was satisfactory; ICC values for replicate measurements were greater than 0.99 for angular measurements and greater than 0.96 for linear measurements. The calculated ICC value was greater than 0.98 for all variables.

The analysis of differences between groups (Table 1) confirmed greater mandibular retrusion (smallest SNB) and greater lower incisor inclination (greater L1.GoMe) for Group 2 in comparison to the other groups (1 and 3). Group 1 had smaller maxillomandibular differences (smallest ANB) and lower facial convexity (smallest NAPog) than the other groups (2 and 3). Despite significant ANOVA result for the U1.L1 measurement, Scheffé's multiple comparison test was unable to detect significant differences between groups.

As shown in Table 1, the RA-RP distance was similar for all groups. Therefore, if image distortions or variations in head position occurred, they were similar for all groups. In contrast, the dental measurements differed significantly among groups. Differences in distance between first upper molars (D6UA-D6UP) and second

upper molars (D7UA-D7UP) were smaller in Group 1 than Group 3; yet the values for these groups did not differ from those of Group 2. Distances between first lower molars (D6LA-D6LP) and second lower molars (D7LA-D7LP) were smaller in Group 1 than Groups 2 or 3. All dental measurements were greater in Group 3 than in Groups 1 or 2.

The proportion of subjects with skeletal and dental mandibular symmetry, skeletal mandibular asymmetry and/or dental mandibular asymmetry was determined in the three groups by means of the IMA using first (IMA1) or second (IMA2) molars as reference. Despite the greater proportion of subjects with skeletal asymmetry in Group 1, the greater proportion of subjects with skeletal and dental symmetry in Group 2 and the greater proportion of subjects with dental asymmetry in Group 3, the chi-square test revealed no significant association between asymmetry and group in IMA1 (Table 2). Additionally, there was no statistically significant difference among the means of IMA1 for each asymmetry category. However, a greater incidence of dental mandibular asymmetry was observed in

Table 1 - Mean and standard deviation of measurements and analysis of variance (ANOVA) to test the hypothesis that the means of the three groups are the same

Cephalometric measurement	Group 1 Class I Mean $\pm$ SD	Group 2 Class II Mean $\pm$ SD	Group 3 Class II Subdivision Mean $\pm$ SD	p
Characterization of the groups				
SNA	82.19 $\pm$ 3.54	81.80 $\pm$ 2.73	83.43 $\pm$ 4.56	0.208
SNB	79.81 ^a $\pm$ 3.23	76.04 ^b $\pm$ 2.82	78.97 ^a $\pm$ 4.33	0.000
ANB	2.37 ^a $\pm$ 2.03	5.77 ^b $\pm$ 2.07	4.46 ^b $\pm$ 2.05	0.000
SN.PP	7.63 $\pm$ 3.14	8.22 $\pm$ 3.58	7.62 $\pm$ 3.85	0.756
SN.OP	19.95 $\pm$ 2.74	19.47 $\pm$ 3.59	19.63 $\pm$ 4.68	0.884
SN.GoMe	34.99 $\pm$ 5.21	34.55 $\pm$ 4.17	32.16 $\pm$ 5.72	0.073
U1.SN	106.20 $\pm$ 7.88	106.81 $\pm$ 6.74	104.93 $\pm$ 7.14	0.597
L1.GoMe	91.49 ^a $\pm$ 8.60	97.50 ^b $\pm$ 6.12	95.49 ^{ab} $\pm$ 6.35	0.005
U1.L1	127.33 $\pm$ 12.90	121.15 $\pm$ 8.52	127.41 $\pm$ 9.84	0.036
NAPog	3.62 ^a $\pm$ 5.12	9.30 ^b $\pm$ 5.62	7.11 ^b $\pm$ 4.91	0.000
Skeletal and dental linear				
RA-RP ⁽¹⁾	1.38 $\pm$ 0.88	1.38 $\pm$ 1.60	1.37 $\pm$ 1.22	1.000
D6UA-D6UP	1.26 ^a $\pm$ 0.79	1.60 ^{ab} $\pm$ 1.19	2.02 ^b $\pm$ 1.23	0.028
D7UA-D7UP	1.27 ^a $\pm$ 0.82	1.57 ^{ab} $\pm$ 1.15	1.96 ^b $\pm$ 1.16	0.045
D6LA-D6LP ⁽¹⁾	1.20 ^a $\pm$ 0.80	1.87 ^b $\pm$ 1.11	2.51 ^b $\pm$ 1.78	0.001
D7LA-D7LP ⁽¹⁾	1.15 ^a $\pm$ 0.75	1.81 ^b $\pm$ 1.10	2.48 ^b $\pm$ 1.81	0.001

⁽¹⁾ Brown-Forsythe statistics (Levene's test rejected the hypothesis of homogeneity of variance).

Group 3 than in Groups 1 or 2, and a greater incidence of skeletal asymmetry was observed in Group 2 than in Groups 1 or 3 (Table 3). When the second molar was used to calculate the IMA2, there was no significant association between asymmetry and group membership (Table 2). Finally, the magnitude of dental mandibular asymmetry in Group 1 was smaller than that in Groups 2 or 3 (Table 3).

The proportion of subjects with dental symmetry, upper dental asymmetry and/or lower dental asymmetry was determined in the three groups by IDA1 and IDA2. A chi-square test revealed significant association between asymmetry and group membership. The proportion of individuals with dental symmetry was significantly greater in Groups 1 and 2 than in Group 3. In Group 3, there was a high frequency of lower dental asymmetry (Table 2). The magnitude of lower dental asymmetry was also greater in Group 3 than in Groups 1 or 2 (Table 3).

DISCUSSION

In this study, lateral radiographs were used to assess the nature of asymmetries in individuals with Class II subdivision (Group 3) compared to control groups of individuals with bilateral symmetric Class I (Group 1) or bilateral symmetric Class II (Group 2) relationship. Although other diagnostic methods are more frequently used than lateral radiography, these methods are accompanied by specific disadvantages.^{6-9,11-17}

Lateral cephalometric radiographs allow anteroposterior structures to be visualized in a simple manner without additional costs to the orthodontist, as they are traditionally required for diagnostic and treatment planning. However, as other radiographic methods, errors in head positioning may occur.²⁰ The head may rotate along transverse, anteroposterior, or vertical axes. Rotations along the transverse axis do not cause image distortions because the head remains parallel to the X-ray source. Rotation produces relative changes in the location of images on the film, but none in

Table 2 - Number and proportion of individuals according to group and category of the index of asymmetry and results of chi-square test for the association between asymmetry and group

Index / Category of asymmetry	Group 1		Group 2		Group 3	
	n	%	n	%	n	%
IMA1 ($\chi^2 = 8.66$; df=4; p=0.070)						
Dental asymmetry	10	33.3	14	46.7	20	66.7
Symmetry	7	23.3	9	30	4	13.3
Skeletal asymmetry	13	43.3	7	23.3	6	20
Total	30	100	30	100	30	100
IMA2 ($\chi^2 = 9.15$; df=4; p=0.057)						
Dental asymmetry	11	36.7	13	43.3	20	66.7
Symmetry	6	20.0	10	33.3	4	13.3
Skeletal asymmetry	13	43.3	7	23.3	6	20.0
Total	30	100.0	30	100.0	30	100.0
IDA1 ($\chi^2 = 16.33$; df=4; p=0.003)						
Dental asymmetry	3	10.0	8	26.7	13	43.3
Symmetry	23	76.7	18	60.0	8	26.7
Skeletal asymmetry	4	13.3	4	13.3	9	30.0
Total	30	100.0	30	100.0	30	100.0
IDA2 ($\chi^2 = 14.60$; df=4; p=0.006)						
Dental asymmetry	3	10.0	7	23.3	12	40.0
Symmetry	23	76.7	19	63.3	9	30.0
Skeletal asymmetry	4	13.3	4	13.3	9	30.0
Total	30	100.0	30	100.0	30	100.0

IMA = index of mandibular asymmetry; IMA1 = (RA-RP) – (D6LA - D6LP); IMA 2 = (RA-RP) – (D7LA – D7LP).
IDA = index of dental asymmetry; IDA1 = (D6UA-D6UP)–(D6LA-D6LP); IDA 2 = (D7UA-D7UP)–(D7LA-D7LP).

Table 3 - Mean and standard deviation of the index of asymmetry and results of the analysis of variance (ANOVA) to test the hypothesis of equality of the means of the three groups, according to the category of asymmetry.

Index / Category of asymmetry	Group 1 Mean $\pm$ SD	Group 2 Mean $\pm$ SD	Group 3 Mean $\pm$ SD	P
IMA1 (RA-RP) – (D6LA – D6LP)				
Dental asymmetry	-1.35 $\pm$ 0.54	-1.89 $\pm$ 0.85	-2.23 $\pm$ 1.12	0.064
Symmetry	-0.21 $\pm$ 0.42	-0.04 $\pm$ 0.28	0.25 $\pm$ 0.29	0.120
Skeletal asymmetry	1.57 $\pm$ 0.68	1.74 $\pm$ 0.57	1.57 $\pm$ 0.73	0.840
IMA2 (RA-RP) – (D7LA – D7LP)				
Dental asymmetry	-1.18 ^a $\pm$ 0.47	-1.97 ^b $\pm$ 0.8	-2.16 ^b $\pm$ 1.22	0.031
Symmetry	-0.12 $\pm$ 0.44	-0.02 $\pm$ 0.31	0.18 $\pm$ 0.21	0.429
Skeletal asymmetry	1.58 $\pm$ 0.67	1.83 $\pm$ 0.78	1.55 $\pm$ 0.73	0.721
IDA1 (D6UA – D6UP) – (D6LA – D6LP)				
Dental asymmetry	-0.80 ^a $\pm$ 0.20	-1.28 ^a $\pm$ 0.24	-2.52 ^b $\pm$ 0.40	0.002
Symmetry	-0.01 $\pm$ 0.57	-0.08 $\pm$ 0.27	0.18 $\pm$ 0.16	0.050
Skeletal asymmetry	1.13 $\pm$ 1.03	0.90 $\pm$ 0.16	1.86 $\pm$ 0.84	0.058
IDA2 (D7UA-D7UP)–(D7LA-D7LP)				
Dental asymmetry	-0.73 ^a $\pm$ 0.23	-1.31 ^a $\pm$ 0.39	-2.70 ^b $\pm$ 1.00	0.001
Symmetry	0.07 ^{ab} $\pm$ 0.26	-0.05 ^a $\pm$ 0.25	0.21 ^b $\pm$ 0.19	0.031
Skeletal asymmetry	1.05 $\pm$ 0.47	0.75 $\pm$ 0.17	1.66 $\pm$ 0.82	0.082

the relationships of structures that could cause errors in the process of radiographic measurement. Rotation along the anteroposterior axis affects vertical measurements. Although bilateral structures move equally, vertical measurements increase or decrease based on the direction of rotation. Rotation along the vertical axis could influence horizontal measurements, as analyzed in this study.²⁰ When the head rotates along the vertical axis, the length of the mandibular body gradually decreases as the rotation angle increases along the direction of the film. Alteration in length is typically approximately 1%; however, this percentage may increase to -5.78% when the angle of head rotation varies between -5 and -15 degrees.²⁰ The effects of head rotation on measurements of mandible and molars are equal in magnitude. Therefore, the absolute but not relative distance between these structures is affected, as demonstrated by the indexes of asymmetry of this current study.

According to Kjellberg et al,¹⁹ radiographic extent, head position and distortions can be ignored when an index is used to calculate linear measurements. Habets et al²⁰ also believe that morphological differences of size, calculation and interpretation of findings can be excluded by certain indexes such as those used in the current study.

Our sample showed a few cephalometric differences related to the characteristics of malocclusion.

For example, individuals in Group 1 presented smaller ANB and less facial convexity. These differences reflect the characteristics of the groups, confirming that individuals in Group 2 presented greater mandibular retrusion than those in Groups 1 and 3. Although Group 3 has a Class II relationship on one side, the Class I relationship on the other side produces smaller retrusion than in individuals with bilateral Class II (Group 2). Azevedo et al⁴ reported that skeletal involvement in individuals with Class II subdivision is typically small. Greater buccal positioning of lower incisors in individuals with Class II arises due to dentoalveolar compensation for their greater mandibular retrusion, which results in a significantly more closed interincisal angle.

Distances between first and second upper or lower molars (Table 2) were always smaller in Group 1 than in Groups 2 and 3, thus revealing that this type of relationship is associated with greater dental symmetry. IDA1 and IDA2 identified greater dental symmetry in Groups 1 and 2, indicating great concordance between our direct measurements and the results of these indexes.

Similarly, IMA1 and IMA2 revealed greater skeletal mandibular asymmetry in Group 1 (Table 2). This result is supported by the findings by Sezgin et al²¹ who found greater asymmetry in individuals with Class I than those with

normal occlusion. They also found²² asymmetry in Class I patients, with the mandible less anterior and highly positioned in hyperdivergent patients than in hypodivergent.

IMA revealed greater skeletal and dental mandibular symmetry in Group 2 than in Groups 1 and 3. Although Group 2 tended to show greater symmetry than individuals in the other groups, their skeletal asymmetry (when present) was greater in magnitude than that of Groups 1 and 3.

IMA revealed greater dental mandibular asymmetry in Group 3 than those in Groups 1 and 2. IDA also showed individuals in Group 3 to have greater lower dental asymmetry than Groups 1 and 2. These results corroborate those presented by authors^{4,7-11} using other diagnostic methods, such as posteroanterior radiography, submentovertex radiography, 45° radiography, study models and photographs. Alavi et al⁶ used lateral radiograph to investigate asymmetries in individuals with Class II subdivision. Nevertheless, the authors were not able to determine whether these changes arose due to dentoalveolar or skeletal etiology.

CONCLUSION

- » Two indexes of asymmetry and direct measurements were presented as part of a new evaluation method used to identify dental and skeletal asymmetries by means of lateral cephalometric radiography.
- » Distances between first and second upper or lower molars were always less in the Class I group and greater in the Class II subdivision group, in accordance with new IDA indexes which identified greater dental asymmetry in individuals with Class II subdivision than those with Class I and Class II.
- » New IMA indexes revealed less skeletal and dental mandibular asymmetry in individuals with Class II, and greater skeletal mandibular asymmetry in individuals with Class I.
- » IMA and IDA suggested that Class II subdivision individuals had greater mandibular dental asymmetry than Class I or Class II.

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Lateral cephalometric radiograph *versus* lateral nasopharyngeal radiograph for quantitative evaluation of nasopharyngeal airway space

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Objective: This study compared lateral radiographs of the nasopharynx (LN) and lateral cephalometric radiographs (LC) used to assess nasopharyngeal airway space in children.

Material and Methods: One examiner measured the nasopharyngeal space of 15 oral breathing patients aged between 5 and 11 years old by using LN and LC. Both assessments were made twice with a 15-day interval in between. Intergroup comparison was performed with t-tests ($P < 0.05$).

Results: Comparison between LN and LC measurements showed no significant differences.

Conclusion: Lateral cephalometric radiograph is an acceptable method used to assess nasopharyngeal airway space.

Keywords: Radiology. Nasopharynx. Orthodontics.

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

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INTRODUCTION

Two modalities of conventional and extraoral radiographs are used to assess nasopharyngeal airway space: lateral nasopharyngeal radiograph (LN), also known as cavum radiography, and lateral cephalometric radiograph (LC). The former is requested most frequently by physicians to assess the nasopharynx of patients with nasal obstruction, whereas the latter has been used for several years in Orthodontics to assess the morphology and development of dental occlusion, including soft and skeletal tissues of the face.^{1,2} Moreover, several authors show that lateral cephalometric radiograph allows one to assess adenoid and dimension of nasopharynx.¹⁻¹¹

With the aim of establishing a baseline for measuring nasopharyngeal space on lateral radiographs, McNamara Jr⁷ defined it as the shortest distance between the convex surface of the adenoid (or posterior wall of nasopharynx) and the dorsal surface of the soft palate. Patients with nasopharynx width less or equal to 5 mm reveal apparent airway obstruction. It is used only as an indicator of possible airway impairment. A more accurate diagnosis can be made only by an otorhinolaryngologist during clinical examination.

According to Kohler¹² and Almeida et al,³ lateral cephalometric radiograph and lateral nasopharyngeal radiograph can be used by orthodontists and otorhinolaryngologists as integrated medical-dental examinations. Moreover, they can be obtained during the same procedure, which eliminates the need for additional radiographic exposure.

Ikino et al² assessed the degree of nasopharynx obstruction by means of applying Cohen and Konak²¹ score to both lateral cephalometric radiograph and lateral nasopharyngeal radiograph. His results revealed that similar outcomes were produced by both radiographs in 73.1% of children. The author stated that lateral cephalometric radiograph yields better results in comparison to lateral nasopharyngeal radiograph, since patient's head positioning is standardized in the former. Head position is fixed in LC, which avoids variation in the sagittal and transverse planes and allows a more secure airway analysis without the artifacts produced by head rotation. This information is important since children hardly remain in the desired position. Based on these findings, the authors concluded that LC is the radiograph of choice for assessing nasal obstruction due to equally showing nasopharynx airway and minimizing changes in head positioning.

According to Almeida et al,³ computed tomography (CT) is also used in diagnosis of nasopharyngeal obstruction; however, despite being more accurate, it is also more expensive. Montgomery et al¹³ evaluated the results obtained by tomography and concluded that radiographic examination is poor in information. The authors suggest that CT should be used as the gold standard. Conversely, cephalometric radiography should be used to determine whether a more detailed tracking is necessary or not, bearing in mind that this is a two-dimensional and, therefore, limited examination.

No previous study compared lateral nasopharyngeal radiograph with lateral cephalometric radiograph used for quantitative evaluation of nasopharynx. For this reason, the objective of this study was to compare lateral cephalometric radiograph and lateral nasopharyngeal radiograph for a quantitative evaluation of nasopharyngeal airway space.

MATERIAL AND METHODS

This research was approved by the Federal University of Paraíba (UFPB) Institutional Review Board under protocol 574/06. All research subjects signed an informed consent form. This study assessed the orthodontic records of patients from the School of Dentistry of the University of São Paulo. In selecting the sample, the following inclusion criteria were applied: patients aged between 5 and 11 years old; recent lateral cephalometric radiograph of good quality (Fig 1A); signs of mouth breathing including open mouth posture, short upper lip and everted lower lip; large, varying degrees of narrow face; small nostrils, and poorly developed, deep, narrow palate which demonstrated the need for otorhinolaryngologist analysis.

The final sample comprised 15 patients who were referred to an otorhinolaryngologist for examination of the nasopharynx. A lateral nasopharyngeal radiograph (Fig 1B) was requested for all patients as a supplementary diagnostic tool. The interval between LC and LN was less than three months. Seven patients (46.7%) were males, whereas 8 (53.3%) were females. Patients had a mean age of 8.07 ± 1.58 years (varying from 5 to 11 years) as shown in Table.

Radiographs were manually traced by the same operator using Ultraphan sheets and a 0.35 mm mechanical pencil. Nasopharyngeal space was measured in millimeters with a ruler, from the point of the anterior half



Figure 1 - A) Nasopharyngeal space measurement expressed in millimeters from the point of the anterior half of the contour of the soft palate (SP) to the nearest point of the pharyngeal wall (PW). B) Lateral nasopharyngeal radiograph (LN). C) Lateral cephalometric radiograph (LC).

of the contour of the soft palate to the nearest point of the nasopharyngeal posterior wall (Fig 1C).

Rotograph Plus (Villa Sistemi Medicali, Buccinasco, Italy) was used for lateral cephalometric radiograph, while Siemens (AG, Munich, Germany) was used for lateral nasopharyngeal radiograph under 10% and 20% image magnification, respectively. Magnification factors were corrected before comparison.

LC was obtained with the patient positioned in a cephalostat with the Frankfurt Horizontal Plane (FHP) parallel to the ground, lips at rest and in centric occlusion. Focus-sagittal midplane distance was 1.52 m and the exposure parameters were 85 KVP, 10 mA and 0.5 to 1 second of exposure time, depending on patient's age.

LN was performed with the child standing in profile with the head horizontally oriented and the mouth closed during inspiration. Focus-sagittal midplane distance was 1.42 m and the exposure parameters were 64 kV and 3.5 mA.

Data were processed in a statistical program (SPSS 11.0) for descriptive and inferential analyses. To calculate error of the method, all radiographs were remeasured after a 15-day interval. The formula proposed by Dahlberg¹⁴ ($Se^2 = \Sigma d^2 / 2n$) was used to estimate the order of magnitude of casual errors, while systematic errors were analyzed by paired t-tests, as advocated by Houston.¹⁵ Independent t-tests were used for intergroup comparison of nasopharynx width in LC and LN (significance level was set at 5%).

RESULTS

Casual errors were 0.56 and 0.07 for LN and LC, respectively. No statistically significant systematic errors were observed (Table 1).

There were no significant differences between nasopharynx measurements in LN and LC (Table 1).

DISCUSSION

Intragroup analyses showed no significant errors when the first and second measurements for lateral nasopharyngeal radiograph and lateral cephalometric radiograph were compared, thus demonstrating good precision and reproducibility of measurements.

Previous studies reported that nasopharynx evaluation is important to diagnose adenoid size and permeability of airway space.^{16,17,18} This study aimed at comparing nasopharynx width in LC and LN. Correction of image magnification of both types of radiograph allowed comparison of nasopharynx measurements. No significant differences were observed between LC and LN (Table 1), corroborating the study by Ikino et al.² These authors conducted a qualitative analysis of nasopharynx and found an agreement in the degree of airway space obstruction for both types of radiographs, an important factor to consider when dealing with patients who will undergo orthodontic treatment and are likely to have lateral cephalometric radiograph requested for diagnosis, regardless of their respiratory condition. For these patients, evaluation of nasopharynx by means of LC can avoid unnecessary financial and biological costs of taking an extra radiographic exam.^{1,19,20}

Table 1 - Patients' age, analysis of systemic and random errors and comparison between nasopharynx width in LC and LN.

Patients' age (years)						
Mean		Standard deviation		Minimum		Maximum
8.07		1.58		5		11
Analysis of systemic and random errors						
First analysis			Second analysis			
	Mean	SD*	Mean	SD*	P**	Dahlberg
Lateral cephalometric radiograph	11.92	5.41	11.66	5.03	0.212	0.56
Lateral nasopharyngeal radiograph	11.47	3.16	11.49	3.17	0.427	0.07
Comparison between nasopharynx width in LC and LN						
Lateral cephalometric radiograph			Lateral nasopharyngeal radiograph			T-test
Mean	SD		Mean	SD		P
11.82	5.22		11.48	3.16		0.385

SD* = Standard deviation P** = 0.05.

The technique used to obtain LC yields better results in comparison to LN, since patient's head positioning is standardized in the former. For this reason, it avoids variations in the sagittal, frontal and transverse planes. Rotation of the head may produce undesired effects, especially in children who do not always remain in a desired position.² In addition, LC has the advantage of having a fixed distance between focal point and film.²¹

Major et al²² assessed the capability of lateral cephalometric radiographs to diagnose hypertrophied adenoids and obstructed nasopharyngeal airway. They conducted a systematic literature review and concluded that LC performed reasonably well in evaluating adenoid size. Quantitative measures of adenoid area and subjective grading of adenoid size on LCs had reasonable correlations with actual adenoid size.

Barbosa et al¹ compared the use of LC and endoscopy of nasopharynx to evaluate nasopharynx obstruction.

They concluded that LC allows visualization of soft and hard tissue structures, in addition to assessing location, configuration and growth of nasopharynx and adenoid tissue. Moreover, it allows structures closely related to oral cavity and nasopharynx to be visualized. Although this type of radiograph has greater limitations in comparison to two-dimensional interpretation of nasopharynx, it has proved to be effective as a diagnostic tool. This fact was evidenced by the strong correlation between LC results and nasal endoscopy.

CONCLUSION

No significant differences were found between measurements obtained with lateral nasopharyngeal radiograph and lateral cephalometric radiograph. Lateral cephalometric radiograph proved an acceptable method to evaluate nasopharyngeal airway space by both the orthodontist and the otorhinolaryngologist.

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Effectiveness of orofacial myofunctional therapy in orthodontic patients: A systematic review

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Objective: The aim of the present systematic review was to determine the existence of scientific evidence demonstrating the effectiveness of orofacial myofunctional therapy (OMT) as an adjuvant to orthodontic treatment in individuals with orofacial disorders. A further aim was to assess the methodological quality of the studies included in the review.

Methods: An electronic search was performed in eight databases (Medline, BBO, LILACS, Web of Science, EMBASE, BIREME, Cochrane Library and SciELO) for papers published between January 1965 and March 2011, with no language restrictions. Selection of articles and data extraction were performed by two independent researchers. The quality of the selected articles was also assessed.

Results: Search strategy resulted in the retrieval of 355 publications, only four of which fulfilled the eligibility criteria and qualified for final analysis. All papers selected had a high risk of bias.

Conclusions: The findings of the present systematic review demonstrate the scarcity of consistent studies and scientific evidence supporting the use of OMT in combination with orthodontic treatment to achieve better results in the correction of dentofacial disorders in individuals with orofacial abnormalities.

Keywords: Myofunctional therapy. Orthodontics. Malocclusion.

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INTRODUCTION

Orofacial myofunctional therapy (OMT) techniques and principles can be used either alone or in combination with other forms of therapy.¹⁻⁷ In combination with Orthodontics, OMT has been reported to be effective in the treatment of myofunctional disorders.^{2,5-11} According to a number of studies, this combination leads to improvements in myofunctional capacity, allows satisfactory growth and development of the maxilla and assists in the adaptation of dentition to the new occlusal pattern.^{8,12,13} However, a critical literature analysis reveals that most studies on this topic have striking methodological differences, heterogeneous samples and a lack of representativity.³ Such limitations have led to divergent results and compromise the quality of evidence, thereby hindering interpretation and clinical application of findings.

OMT generally involves exercising the facial and cervical muscles to improve proprioception, tone and mobility.^{1,14-18} The main objectives are the treatment of disorders of the stomatognathic system, such as orofacial abnormalities, mouth-breathing pattern, lip incompetence, tongue thrust habit, mandibular deviation and improper joint patterns during speech; chewing and swallowing, as well as assistance in the correction of parafunctional oral habits, such as thumb-sucking and bruxism.^{1,14-24} In some cases, OMT may also assist in improving body posture, thereby contributing to overall health.^{1,14-18}

Since orofacial disorders increase the degree of difficulty of orthodontic treatment and contribute to the relapse of dentofacial abnormalities,^{8,9,11} OMT may be favorable to orthodontic treatment. Although the literature reports the combination of these therapies to be fundamental to achieve a satisfactory outcome in orthodontic treatment, there have been no systematic reviews carried out to investigate whether this combination is truly capable of achieving better results regarding dentofacial disorders in individuals with orofacial abnormalities.

The aim of the present systematic review was to determine scientific evidence that confirms the effectiveness of OMT as a complement to orthodontic treatment in individuals with orofacial disorders. A further aim was to assess the methodological quality of the studies included in the review.

MATERIAL AND METHODS

Eligibility criteria were defined by the authors prior to beginning the study. *In vivo* prospective, longitudinal studies and randomized and/or controlled clinical trials that evaluated the effectiveness of OMT combined with orthodontic treatment in healthy patients with dentofacial deformities were included in the review. Case reports, case series, review articles, opinions and *in vitro* studies were excluded. No restrictions were made with regard to language.

Type of intervention

Orthodontic treatment combined with OMT in patients with malocclusions and/or deficiencies in the vertical, sagittal and transverse directions and/or orofacial dyskinesia.

Search strategy

Searches were performed in the following electronic databases:

- » BIREME – Latin American and Caribbean Center of Health Sciences (www.bireme.br).
- » LILACS – Latin American and Caribbean Literature on Health Sciences.
- » MEDLINE – Medical Literature Analysis and Retrieval System Online.
- » Web of Science – Referential database with abstracts in the fields of science, social science, arts and humanities.
- » Cochrane Library (<http://cochrane.bvsalud.org>) – database of papers with a high degree of scientific evidence, including systematic reviews, controlled clinical trials, etc.
- » BBO – Brazilian Library of Dentistry.
- » SciELO – Online Electronic Scientific Library.

A search was performed for articles published between January 1965 and March 2011, using the following keywords: “myofunctional therapy”, “oral myofunctional therapy”, “orofacial myofunctional therapy”, “myofunctional therapy effectiveness”, “orthodontic treatment and therapy myofunctional”, “myofunctional therapy and orthodontics”. All these keywords were used in all the aforementioned databases.

Selection criteria and data extraction

Three selection phases were carried out by two independent researchers, with differences in opinion

settled by consensus. Initially, all titles were analyzed to eliminate irrelevant publications, review articles, studies involving animals and *in vitro* studies. All abstracts of the publications selected in the first phase were then analyzed and only those referring to prospective, longitudinal studies and randomized clinical trials were included. The full texts of the articles selected in the second phase were read and eligibility was based on the evaluation of effectiveness of OMT in combination with orthodontic treatment.

A table was constructed with data from all studies and the findings were discussed. The following data were recorded: author, year of publication, study design, study groups, sample, age, methods/measures and assessment of results. A high level of agreement between the two researchers was achieved in this phase.

Quality assessment

Methodological quality of studies was assessed with a combination of criteria established by Moose²⁵ and

Prisma.²⁶ The risk of bias was considered low when all the following criteria were reported: 1) randomized sample selection; 2) definition of inclusion and exclusion criteria for the sample; 3) declaration of losses during follow-up; 4) use of validated measures; and 5) adequate statistical analysis. When one of these criteria was absent, the risk of bias was considered moderate. When two or more criteria were absent, the risk of bias was considered high.

RESULTS

Search strategy resulted in 355 articles. Respecting all selection phases based on the eligibility criteria, four articles qualified for final analysis. Figure 1 displays the different steps of the selection process. Table 1 offers a detailed analysis of each article selected for the present systematic review.

Quality of studies

All articles included in this review had a high risk of bias (Table 2). None of the papers selected presented information on randomized selection of the sample or definition of the inclusion and exclusion criteria.

DISCUSSION

The present findings should be interpreted with caution, as only four papers met the eligibility criteria established and none exhibited a high degree of scientific evidence.^{2,5,6,7} Thus, while the studies selected indicated the efficacy of OMT in the correction of dentofacial disorders when combined with orthodontic treatment, the scarcity of consistent studies underscores the lack of scientific evidence on the actual effectiveness of OMT as a complement to orthodontic treatment.

From a methodological standpoint, all papers employed adequate statistical tests for data analysis.^{2,5,6,7} However, the considerable diversity of tests, together with the low number of studies included in the present review, impede carrying out a meta-analysis. Comparisons with other studies are also limited due to differences in study design, sample selection and sample size.

Two studies included in the present systematic review^{5,7} were carried out to determine the effectiveness of OMT alone (control group) and in combination with

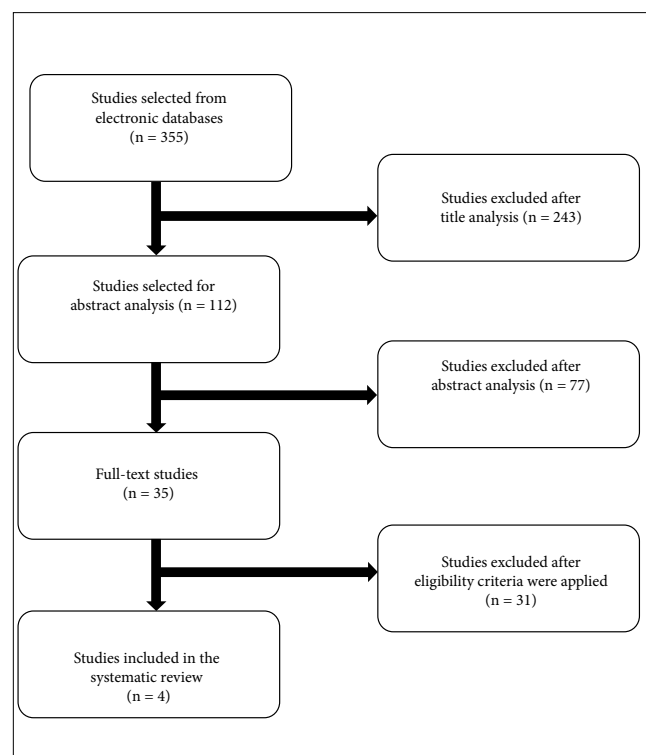


Figure 1 - Flowchart of article selection process.

Table 1 - Characteristics of studies selected.

Author (year)	Study design	Study groups	Sample	Age	Methods/ Measures	Assessment of results
Trawitzki et al ⁶	LS	Experimental group: *P1 (before surgery): patients with Class III malocclusion *P3 (same patients 3 years and 3 years and 8 months after surgery): Finalization of orthodontic treatment and OMT Control group: Individuals without morphological facial abnormalities	13 15	21/42	Ultrasound of masseter muscle at rest and occlusion Linear regression test	Significantly greater ($P < 0.01$) masseter muscle thickness (cm) in P3 group
Smithpeter and Covell Jr ²	LS	Patients with anterior open bite Experimental cohort group: Individuals who received orthodontic treatment or retreatment and OMT Control cohort group: Individuals with history of orthodontic treatment with relapse of open bite	27 49	8/41	T-test Analysis of covariance Linear regression Correlation coefficient	- Relapse was 0.5 mm in experimental group and 3.4 mm in control group (significant difference) - OMT combined with orthodontic treatment was more effective in closure and maintenance of closure of anterior open bite in comparison to orthodontic treatment alone
Daglio et al ⁵	CCT, LS	Patients with malocclusions, deficiencies in vertical, sagittal and transverse dimensions and orofacial dyskinesia Control group (A): Treated with OMT alone Experimental group (B): treated with combined OMT and orthodontic appliance	13 15	8/17	Statistical homogeneity Payne test Frequency analysis	- Group A: Reduction in overjet from 3.5 to 2.6 mm; angle of base of mandible reduced from 30° to 28.31°; ANB angle reduced from 4.4° to 2.7°; statistically significant changes; better results with correction of overbite, which was normalized from a mean of -2.46 to 3.06 mm - Group B: Reduction in overjet from 6.6 to 2.6 mm; overbite improved from mean of -1.2 to +2.9 mm; angle of base of mandible reduced from 31.2° to 27.8°; ANB angle reduced from 7.3° to 3.7°
Daglio et al ⁷	CCT, LS	Patients with orofacial dyskinesia and anterior open bite Experimental group: OMT + orthodontic treatment Control group: OMT alone	75	6/22	Payne test Homogeneity test Cephalometric analysis Correlation analysis Frequency analysis	Combination of OMT and orthodontic treatment was more successful in correction of resting lip posture than OMT alone

LS – Longitudinal Study, CCT – Controlled Clinical Trial.

Table 2 - Quality assessment of studies selected.

Quality criteria	Trawitzki et al ⁶	Smithpeter and Covell Jr ²	Daglio et al ⁵	Daglio et al ⁷
Randomized sample selection	No	No	No	No
Definition of inclusion and exclusion criteria	No	No	No	No
Declaration of losses during follow-up	No	Yes	No	No
Use of validated measures	Yes	Yes	No	No
Adequate statistical analysis	Yes	Yes	Yes	Yes
Estimated potential risk of bias	High	High	High	High

orthodontic treatment (experimental group). In one of these studies,⁵ the authors assessed patients with malocclusions, deficiencies in the vertical, sagittal and transverse dimensions and orofacial dyskinesia. Based on the findings, the authors report that patients with dyskinesia and malocclusions can be treated with both forms of therapy. In the other study involving only patients with orofacial dyskinesia and anterior open bite,⁷ the researchers found that the combination of OMT and orthodontic treatment was more successful in correcting lip incompetence than OMT alone. While their findings favor a combined therapeutic approach, the authors report that the decision regarding the use of OMT alone or in combination with orthodontic treatment is not conclusive and better planned studies are needed. Moreover, both studies have a high risk of bias and a substantial limitation, namely, that only one group was submitted to orthodontic treatment. Thus, the difference between groups is mainly related to the administration of orthodontic treatment.

Another article analyzed herein² assessed the effectiveness of OMT as a complement to maintaining closure of anterior open bite following orthodontic treatment or retreatment. The main conclusion was that the relapse of open bite in the experimental group treated with both orthodontics and OMT (0.48 ± 0.8 mm) was significantly less than that in the control group treated with orthodontics alone (3.38 ± 1.3 mm) ($P < 0.0001$). Therefore, the authors indicate the combination of these two forms of therapy for anterior open bite and stress the importance of documenting the oral and functional habits of each patient, along with the traditional orthodontic records, in any study aimed at assessing the efficacy of treatment for open bite. Such an investigation would allow one to determine what kind of patients would benefit from the combination of OMT and orthodontic treatment and what kind of patients would have a good prognosis with the use of orthodontic appliances alone.

The most recent paper selected for this review⁶ assessed the effect of integrated treatment combining

orthodontics, orthognathic surgery and OMT on the thickness of the masseter muscles in patients with Class III deformity. Although the study included orthognathic surgery as part of orthodontic treatment, the authors found that combined treatment with OMT and orthodontics led to an improvement in masseter muscle thickness in patients following orthognathic surgery in comparison to baseline and the control group. However, these findings should be interpreted with caution considering the high risk of bias as well as the fact that the difference between groups may have been related to the surgery itself, which was likely the main reason for the improvement in muscle thickness.

To reiterate, while the studies selected for the present systematic review indicate effectiveness of OMT in correcting dentofacial deformities when combined with orthodontic treatment, a number of limitations are found, especially with regard to the number and quality of the studies analyzed. Moreover, the papers investigated specific occlusal problems, such as anterior open bite, orofacial dyskinesia and masseter muscle thickness, which make the results quite particular to specific conditions. As one third of the population requires orthodontic treatment,²⁷ further studies with more rigorous methods, such as randomized, controlled clinical trials, should be carried out to determine the actual effectiveness of OMT as a complement to orthodontic treatment.

CONCLUSION

The findings of the present systematic review demonstrate a scarcity of consistent studies and scientific evidence supporting the use of OMT in combination with orthodontic treatment to achieve better results in the correction of dentofacial disorders in individuals with orofacial abnormalities. Studies with a high standard of quality and better study design are needed to establish strong scientific evidence that supports the indication of this form of combined therapy.

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Orthodontic post-adjustment pain control with acupuncture

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Objective: This study aimed to evaluate the analgesic efficacy of systemic acupuncture therapy on the pain caused after orthodontic adjustments.

Methods: An initial sample of 30 orthodontic patients with fixed appliances monthly adjusted was selected; however, only 11 participants completed the study. For this reason, final sample comprised these patients' data only. Initially, average pain levels were assessed at different periods by means of an analogue visual scale (VAS) for three months without acupuncture. In the following three months, the volunteers were submitted to systemic acupuncture sessions on Hegu (LI4) and Jiache (St6) points, before orthodontic adjustments were carried out.

Results: Results revealed statistically significant reduction in pain level indexes both for men ($P = 0.030$) and women ($P = 0.028$) when acupuncture therapy was performed prior to orthodontic adjustment. Patients did not present any side effects.

Conclusion: Acupuncture is a safe and effective method in reducing orthodontic post-adjustment pain.

Keywords: Orthodontics. Acupuncture analgesia. Pain.

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INTRODUCTION

Dental therapy in general, including orthodontic treatment, usually causes pain or distress. Pain is considered a very subjective symptom, for this reason, it is best defined as: "An uncomfortable sensory and emotional experience associated with real or potential injuries or described in terms of such injuries".¹ Individual's past experiences, emotional state, cultural background, age and sex^{2,3} are among the facts that influence pain level, all of which may pose difficulties in measuring symptoms.

The literature shows that all orthodontic procedures, such as separator placement, fixed orthodontic appliances installation and activation, and orthopedic force application, cause pain. Additionally, fixed appliances tend to cause more pain than removable or functional ones, and the correlation between applied forces and pain is small.⁴

There are two major forms of distress caused by fixed orthodontic appliances: traumatic ulcers and pain during orthodontic movement.

In case of traumatic ulcers, orthodontic appliance functions as a traumatic factor that lesions the mucosa and causes epithelial tissue loss, thereby exposing subjacent conjunctive tissue and causing pain by local nociceptors stimulation.

As for orthodontic movement, there are no doubts that pain perception is part of the inflammatory reaction caused by blood flow alterations after orthodontic forces are applied. As a result, many chemical mediators are released as follows: Substance P, histamine, enkephalin, dopamine, serotonin, glycine, glutamate, gamma-aminobutyric acid (GABA), prostaglandin, leucotriene, cytokine; thereby causing local hyperalgesia.^{4,5} Bergius et al³ analyzed 203 orthodontic patients, and demonstrated that 91% of them reported pain caused by orthodontic appliance, whereas 39% reported pain in every orthodontic appointment while adjustment was carried out. Studies show that nearly 95% of patients under orthodontic treatment present different levels of discomfort,^{6,7} especially within the first 24 hours after orthodontic adjustment. Pain caused by fixed orthodontic treatment gradually increases 4 hours after appliance adjustment, returning to normality on the seventh day.^{2,7,8,10}

Studies reveal that the first 48 hours of pain after orthodontic adjustment cause as much disturbance

as to interfere in patient's sleep and induce the need for medication. Krishnan⁴ conducted a literature review and found that nearly all orthodontic patients report moderate to extreme difficulty in chewing and swallowing solid food because of pain, proving that orthodontic pain can also interfere in patient's diet, thus raising another major concern for patients and professionals.

Erdoğan and Dinçer¹¹ reported that nearly 50% of their patients suffered pain within 6 hours to two days after orthodontic adjustment, which interfered in their daily activities. The authors also reported a reduction in pain intensity and the number of patients with pain from the third day on.

Considering the high rate of patients complaining about pain suffered during orthodontic treatment, different methods have been tested for its control, namely: low-level laser (LEDs) application, transcutaneous electrical nerve stimulation (TENS), neural stimulation, vibration to stimulate periodontal ligament, among others resulting in pain control.⁵

In addition to conventional techniques, researchers have sought new procedures for pain control. As a result, Dentistry is trying alternative methods to aid professionals bring more comfort to their patients. Nevertheless, new methods do not include the development of new ultra-modern equipments and/or last generation drugs, only. Researches show that ancient techniques are scientifically efficient in pain control, and acupuncture is among the most effective ones.

The present study assessed the analgesic efficacy of systemic acupuncture therapy on pain caused after orthodontic adjustments. The tested hypotheses were whether acupuncture was efficient or not in reducing pain caused by orthodontic adjustment.

MATERIAL AND METHODS

This research was approved by the Ethics Committee on Human Research under protocol 00080375000-08. All volunteers filled an informed consent form.

This research was conducted as a blind study. The researcher responsible for acupuncture was aware of the treatment modality each patient would be submitted to. However, results were analyzed by a statistician unaware of the treatment to which each volunteer was subjected to.

Patients under fixed orthodontic treatment at the Graduate Program Orthodontic Clinic participated in this research. First, research volunteers were selected. To be included in the group, the patient had to be complaining of pain after orthodontic adjustment and accept acupuncture treatment. Thirty patients volunteered, although, only 11 (7 women and 4 men) concluded the study. Patients' mean age was of 16.2 years (Table 1). The volunteers were monthly assessed during 6 months by means of a visual analogue scale (VAS) for pain. Each scale corresponds to a 10-cm horizontal line with two points meaning "no pain" and "the worst pain possible". Participants were instructed to mark a transversal trace on the line, representing the equivalence of pain intensity they felt.³

VAS allowed pain to be quantified during different periods (before orthodontic adjustment, right after adjustment, 4, 8, 24 and 72 hours after adjustment). Each participant received 7 scales every month in accordance with previously described periods. In the following appointments, the scales were filled and collected for analysis which measured each scale with a millimetric ruler so as to obtain numerical data.³

Within the first 3 months, the volunteers were instructed to fill out VAS after orthodontic adjustment so as to obtain an average of participant's pain without acupuncture treatment. In the following 3 months, antisepsis of the areas of needle insertion was done with cotton and 70% alcohol 5 minutes prior to each orthodontic adjustment. Subsequently, systemic needles were inserted at Hegu (LI4) and Jiache (St6) points on both sides. The needles remained in place for twenty minutes.¹² Dragon® Sterile stainless steel needles (0.20 x 25 mm) were used.

New VASs were filled out during the same periods previously described. Results were used to calculate the average pain described by each patient during the three orthodontic adjustment appointments after acupuncture therapy. Therefore, volunteers performed self-analyses.

Patients were instructed not to take any other analgesic medication while the effect of acupuncture therapy was being analyzed. Should pain be too intense so as to require analgesic medication, the instruction was to record the date, time, type and doses of medication.

Analysis of results of the 11 volunteers was carried out with Sigma-Stat statistic program. Data was first

submitted to analysis of variance (ANOVA) ($P \leq 0.05$). Should ANOVA yield significant values, Tukey test was used to identify significant differences between the average pain level obtained through VAS.

RESULTS

Since significant statistic differences were found in pain perception between male and female patients, results were separately assessed according to that variable.

Variation of pain perception according to time

Results reveal a gradual increase in volunteers' pain level right after orthodontic adjustments and within the first 24 hours with gradual reduction during the following periods. Table 2 and Figure 1 show the averages between female and male patients.

General pain level average of male and female volunteers with and without acupuncture therapy

Analysis of variance (ANOVA) followed by Tukey test at a 5% significance level was conducted between male and female patients and showed a statistically significant difference in pain level after orthodontic activation with or without previous acupuncture therapy. Results are shown in Table 3 and Figure 2.

Average pain level of female volunteers during different periods with and without acupuncture

Averages obtained with or without acupuncture treatment at different studied periods submitted to analysis of variance (ANOVA) at 5% significance level between male and female patients showed that although there was a reduction in pain level during all periods when acupuncture was performed before orthodontic adjustments, it was only statistically significant during the pre-orthodontic adjustment period. Results are shown in Table 4 and Figure 3A.

Table 1 - Volunteers' age and sex.

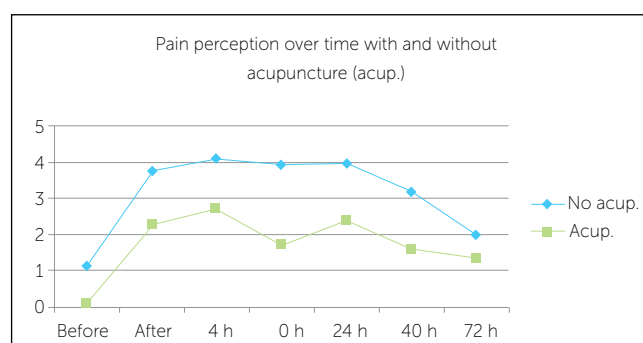
Sex	Mean $\pm$ SD
Female	15.33 $\pm$ 3.933
Male	17.4 $\pm$ 3.43
Total	16.2 $\pm$ 3.68

Table 2 - Average pain level alterations over time.

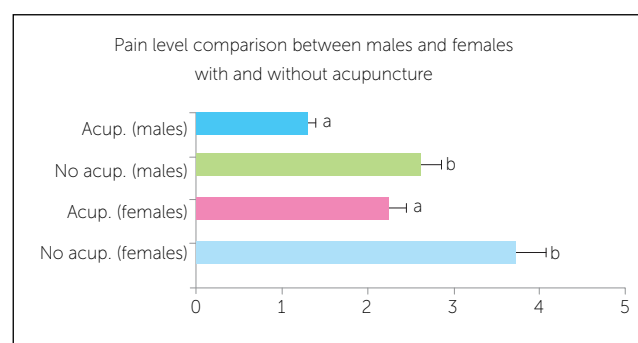
	Before*	After**	4 h	8 h	24 h	48 h	72 h
Without acupuncture	1.08	3.76	4.09	3.96	3.965	3.2	2
With acupuncture	0.104	2.2504	2.711	1.71	2.4	1.6	1.29

* Before orthodontic adjustment.

** Right after orthodontic adjustment.

**Figure 1** - Average pain perception alteration over time, with and without previous acupuncture therapy.**Table 3** - Average values of pain level after orthodontic adjustment with or without previous acupuncture therapy in male and female volunteers. Data expressed as mean $\pm$ standard deviation.

Treatment	Mean $\pm$ SD
Without acupuncture male	2.61 $\pm$ 1.263
With acupuncture male	1.27 $\pm$ 0.677
Without acupuncture female	3.72 $\pm$ 1.129
With acupuncture female	2.22 $\pm$ 1.113

**Figure 2** - Average (and standard deviation) of male and female volunteers' pain level after orthodontic adjustment with or without previous acupuncture therapy. The comparison using distinct letters through Tukey test statistically distinguishes the averages among themselves.

Average pain level of male volunteers during different periods with and without acupuncture

Analysis of variance (ANOVA) was performed at 5% significance level among male participants during different periods with and without acupuncture and revealed a statistically significant difference in pain level 8 hours after orthodontic adjustment, only. Nevertheless, there was a visual reduction in the levels of pain perception recorded during all periods. Results are shown in Table 4 and Figure 3B.

DISCUSSION

Even if analgesic and anesthetic medications are used, dental therapy, including orthodontic treatment, is acknowledged by most people to cause pain or even a light distress. The literature shows that all orthodontic procedures, such as separator placement, bracket installation and activation, and the application and activation of orthopedic forces, cause pain. Additionally, fixed appliances cause more pain than removable or functional ones and the correlation among applied forces and pain felt by patients is small.⁴

Table 4 - Average values of pain levels in different periods with or without previous acupuncture (acup.) treatment in female and male volunteers. Data expressed as mean $\pm$ standard deviation.

	Before	After	4 h	8 h	24 h	48 h	72 h
No acup. (female)	1.77 $\pm$ 1.68	4.21 $\pm$ 2.69	4.36 $\pm$ 2.39	4.63 $\pm$ 1.84	4.3 $\pm$ 2.22	4.31 $\pm$ 1.88	2.43 $\pm$ 1.90
Acup. (female)	*0.02 $\pm$ 0.03	2.92 $\pm$ 2.34	3.34 $\pm$ 2.11	2.50 $\pm$ 2.49	2.90 $\pm$ 2.64	2.20 $\pm$ 1.94	1.64 $\pm$ 2.03
No acup. (male)	0.4 $\pm$ 0.62	3.32 $\pm$ 1.77	3.83 $\pm$ 1.67	3.3 $\pm$ 1.64	3.63 $\pm$ 1.96	2.22 $\pm$ 1.52	1.6 $\pm$ 2.38
Acup. (male)	0.18 $\pm$ 0.29	1.59 $\pm$ 2.10	2.08 $\pm$ 2.17	*0.93 $\pm$ 0.39	2.03 $\pm$ 0.88	1.18 $\pm$ 2.39	0.95 $\pm$ 1.54

* $p < 0.05$.

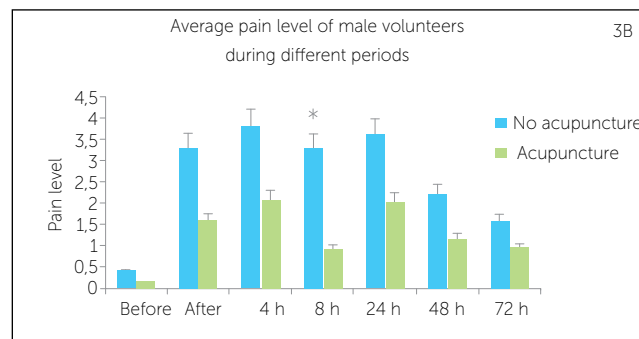
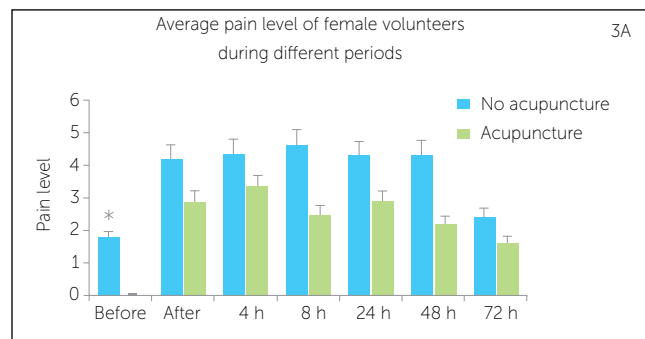


Figure 3 - Average pain level (and standard deviation) of female (A) and male (B) volunteers during different periods of orthodontic adjustment with and without previous acupuncture treatment. * $p < 0.05$.

Among the facts that influence pain level are: former experiences, emotional state, cultural background, age and sex,^{2,3,18} all of which may pose difficulties in measuring the symptom. Except for patient's age and sex, which can easily be assessed, all other factors are quite personal and can be considered as limitations of the present study, since they were not considered as variants that influence pain levels and could interfere in the results.³ Participants' motivation and expectations towards the acupuncture analgesic effect also seem not to influence the results. Since the average values were monthly collected, participants had no access to former analyses and could hardly compare the records in a way that allowed them to forge final results. This could be considered a limitation of this study. Ideally, Sham acupuncture (needle applications at non-analgesic points) should have also been used; however, once a great number of participants quit, it was impossible to divide the group due to the limited number of volunteers comprising the sample. Further studies will be able to correct this fact.

Considering the high rate of patients complaining about pain suffered during orthodontic treatment, different methods have been tested for its control, namely: Low-power laser (LEDs) application, transcutaneous electrical nerve stimulation (TENS), neural stimulation, vibration to stimulate periodontal ligament, among others resulting in pain control.⁵ In addition to conventional techniques to control pain, Dentistry has introduced alternative methods to aid professionals bring more comfort to their patients. Those alternative techniques have been acknowledged and approved by the Federal Council of Dentistry (Resolution 82, July, 2008), and can be applied to reduce pain in dental patients. Acupuncture is one of the most effective techniques.

The aim of the present study was to assess the analgesic efficiency of systemic acupuncture performed before orthodontic adjustment to treat orthodontic post-adjustment pain. The research started with 30 patients gathered from an Orthodontic Graduate Program, but

only 11 participants concluded it. Some degree of desistance is expected during human research. No volunteers declined to participate in this study due to its methodology. A great number of absences during orthodontic adjustment appointments were observed, thereby eliminating some participants. In some cases, the orthodontist responsible for the orthodontic adjustment was absent, which also hindered patient's participation on the research. All volunteers had their pain level analyzed by Visual Analogical Scales (VAS).

VAS was chosen due to being greatly used to measure pain and having some advantages among verbal scales, such as the facility children have in filling it out.¹³ Patients were asked to register the intensity of pain they felt on the line representing the estimate variable.¹³ A numerical value was assigned by the researcher using a millimetric ruler. Consequently, precise values were not possible.¹⁴ No volunteers had difficulties in filling out the scales, reinforcing their easiness.

Bergius et al³ assert that pain caused by orthodontic adjustment can be immediate or delayed. Immediate pain occurs after the archwire is attached and periodontal ligament is compressed. The latter starts a few hours later when hyperalgesia of periodontal ligament generates allodynia through the release of chemical active substances (as prostaglandin, histamine and substance P), thereby causing partial depolarization of afferent fibers, neural facilitation and peripheral sensitization. When an orthodontic force is applied to a tooth, an initial distress and/or pain phase of 1 or two days usually occur.¹⁰ The intensity of pain generally increases within 4 to 24 hours and then reduces to normal levels within a 7-day period.³ There is generally a circadian variation in pain intensity, with an increase of pain between late afternoon and night, although that does not intensely interfere in sleep.⁸ Our results confirm the fact that pain begins after orthodontic adjustment, its apex occurs within 8 to 24 hours and gradually reduces over time, even with previous acupuncture treatment. However, the present work shows that intense decrease occurs when acupuncture treatment is previously performed.

Scheurer⁷ also showed that general pain intensity perception, analgesic taking, pain during feeding and distress influence on daily life were significantly greater in women than men. Women are more sensitive to

experimental painful stimuli than men, with clinical pain of greater frequency and severity lasting for a longer period of time and in a larger range of body locations.^{15,16} In the present study, we also observed greater feminine pain sensitiveness, with or without previous acupuncture treatment. This fact could be related to women's great hormonal variability, mainly in female teenagers voluntaries. For both males and females, acupuncture treatment significantly reduced pain after orthodontic adjustments, thus proving its efficiency.

Even when results showed a reduction in pain levels after acupuncture treatment during all studied periods (both for men and women), it was only statistically significant during two periods. Before orthodontic adjustment in female patients, which is justified by their hormonal alterations — a limitation for the study since their menstrual period was not assessed. For men, within 8 hours after adjustment, corresponding, according to the literature, to the time of pain apex.³

Pain reduction observed in the present study probably occurred due to acupuncture action mechanism, activating descending pain inhibition and antinociceptive substances release, such as β -endorphin (analgesics), cortisol (anti-inflammatory) and serotonin (antidepressant) in the blood flow and cephalorachidian liquid.¹⁷

Data obtained in the present study confirm the efficiency of acupuncture as a complementary treatment in Orthodontics. It is important since nearly all orthodontic patients, as described in many studies, report moderate to extreme difficulty in chewing and swallowing solid food because of pain, proving that orthodontic pain can also interfere on patient's diet, a major concern for patients and professionals.⁴ Also, Erdiç and Dinçer¹¹ reported that nearly 50% of their patients suffered from pain that interfered on their daily activities within 6 hours to two days after orthodontic adjustments, which could be diminished by stimulation of analgesic points through acupuncture, as shown in the present study.

The literature highlights many analgesic acupuncture points. Microsystems of acupuncture such as ear acupuncture, hand acupuncture and scalp acupuncture points are another treatment option, instead of systemic acupuncture. Hegu (LI4) and Jiache (St6) points were used for its location and professional easy access.

Acknowledgment and approval of acupuncture practice as a complement to dental treatment, issued by the Federal Council of Dentistry in July 2008, will certainly bring progress in this matter, since national researches using acupuncture for dental treatment are few and, for this reason, narrow the benefits of the method for both patients and professionals. Acupuncture does not produce side effects and can be safely practiced by a qualified professional. In this study, a total of 33 acupuncture sessions were done (3 on each one of the 11 volunteers), and no patients presented side effects related to needle insertion.

The fact that it is not an onerous technique is important and must also be observed, particularly considering the present social-economic situation in Brazil.

CONCLUSION

Within the limitations and conditions of this experiment, it is reasonable to conclude that systemic acupuncture treatment performed before orthodontic therapy can reduce pain level in both men and women. Additionally, acupuncture proves to be a safe technique employed for this purpose.

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Tooth-size discrepancy: A comparison between manual and digital methods

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Introduction: Technological advances in Dentistry have emerged primarily in the area of diagnostic tools. One example is the 3D scanner, which can transform plaster models into three-dimensional digital models.

Objective: This study aimed to assess the reliability of tooth size-arch length discrepancy analysis measurements performed on three-dimensional digital models, and compare these measurements with those obtained from plaster models.

Material and Methods: To this end, plaster models of lower dental arches and their corresponding three-dimensional digital models acquired with a 3Shape R700T scanner were used. All of them had lower permanent dentition. Four different tooth size-arch length discrepancy calculations were performed on each model, two of which by manual methods using calipers and brass wire, and two by digital methods using linear measurements and parabolas.

Results: Data were statistically assessed using Friedman test and no statistically significant differences were found between the two methods ($P > 0.05$), except for values found by the linear digital method which revealed a slight, non-significant statistical difference.

Conclusions: Based on the results, it is reasonable to assert that any of these resources used by orthodontists to clinically assess tooth size-arch length discrepancy can be considered reliable.

Keywords: Dental models. Computer-assisted diagnosis. Three-dimensional imaging.

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INTRODUCTION

Plaster models provide a three-dimensional view of occlusion, allowing professionals to assess in greater detail the impressions obtained during clinical examination without interference from soft tissues of the mouth, which facilitates the study of a case.^{1,2,3} Thus, the use of models is vital if one is to reach an accurate diagnosis.^{1,4-9}

With the aid of orthodontic models, the clinician can assess symmetry, arch form, severity of the curves of Spee and Wilson, axial inclinations as well as perform analyses such as Peck and Peck, Bolton and Tooth Size-Arch Length Discrepancy.¹⁰

Tooth size-arch length discrepancy (TSALD), or Space Analysis, plays a pivotal role in orthodontic practice, being represented by the following formula: $TSALD = \text{Space Available} - \text{Space Required}$, where the Space Available (SA) represents the basal region available in the dental arch, and the Space Required (SR) is equal to the sum of mesiodistal diameters of existing teeth. Diagnostic decisions to determine whether extractions are necessary to accommodate teeth in the dental arch are usually made based on this evaluation along with other factors such as cephalometric and profile analyses.^{1,2,5,11,12}

Lately, there have been significant advances in computer science of which effects have been increasingly felt in different areas of dental practice. In Orthodontics, these advances have been particularly significant in terms of diagnostic tools.^{3,13,14}

Similarly to digital photographs and radiographs developed to replace their analogical counterparts, thereby facilitating diagnosis and interdisciplinary planning, plaster model scanning has also gained momentum through the development of 3D scanners.^{1,4,6,15} According to Dubón,¹¹ these resources have been widely employed in orthodontic practice.

Three-dimensional scanners are devices used to convert volumetric objects into three-dimensional digital images. In other words, they analyze a real-world object and collect data on its shape and appearance, turning it into a three-dimensional digital file.¹⁶ Three-dimensional plaster model scanning is advocated by many authors as a viable option to overcome existing limitations in handling traditional plaster casts. Furthermore, they allow clinicians to obtain measurements of models more rapidly.^{5,17-22}

Different technologies have been developed to build 3D scanning devices, each with their own limitations, advantages and disadvantages.¹ Thus, in view of ongoing technological advances, the many benefits offered by recent resources and the availability of several different brands of 3D scanners in the market — such as 3Shape's R700™ scanner and its associated software OrthoAnalyzer™ — it becomes necessary to assess the reliability of tooth size-arch length discrepancy measurements performed on three-dimensional digital models and compare these measurements with those obtained from plaster models by means of traditional methods.

MATERIAL AND METHODS

This study was approved by the Federal University of Bahia (UFBA) Institutional Review Board under protocol #235,134, and registered by the Brazilian National Research Ethics Committee (CONEP) under CAAE 12489513.2.0000.5024.

This study adopts an experimental approach using plaster models (casts) and three-dimensional digital models captured with a R700™ scanner manufactured by 3shape, and measurements performed with 3Shape OrthoAnalyzer™ software, a digital caliper and brass wire.

Characterization of the sample

Thirty mandibular casts of patients in the initial phase and with permanent dentition were selected. Inclusion criteria were as follows:

- Absence of positive or negative bubbles.
- Presence of all teeth, from #36 to 46.
- Teeth in perfect condition, with no anatomical defects.

Tooth size-arch length discrepancy

Four calculations were performed for each patient.

Two calculations by manual methods:

» **TSALD 1 = SA (caliper) - SR**

» **TSALD 2 = SA (brass wire) - SR**

And two calculations by digital methods:

» **TSALD 3 = SA (linear) - SR**

» **TSALD 4 = SA (parabola) - SR**

Model manipulation

Obtaining manual measurements

Material used to obtain manual measurements not only included plaster models, but also index cards for

data recording, a Cen-Tech 4-in digital caliper (Harbor Freight Tools, Calabasas, CA, USA) with 0.01 mm accuracy, brass wire, a ruler, pencil and eraser.

Initially, the space required (SR) was recorded with the aid of a digital caliper. Each value was obtained by placing the caliper over the largest mesiodistal width of lower teeth, starting from the second right premolar (Fig 1), followed by the first premolar, canine and incisors on the same side. The procedure was repeated on the left side, starting from the incisor, followed by the canine, first and second premolars. Measurements were recorded on the index cards.

After this step, the space available (SA) was measured, which corresponds to the size of the basal bone lying between the mesial surface of the first permanent molar on one side to the mesial surface of the first permanent molar on the opposite side. This measurement was obtained by two different methods. The first involved the use of a digital caliper to measure the SA. Thus, the caliper was positioned from the mesial region of the lower right first molar to the mesial surface of the canine (Fig 2), and from the mesial surface of the canine to the region between central incisors (Fig 3). The same procedure was carried out on the opposite side, starting from the region between incisors.

After being recorded with a digital caliper, SA was measured with the aid of brass wire. A parabola was, therefore, formed with brass wire contouring the central grooves of the occlusal surfaces of posterior teeth and the incisal surfaces of anterior teeth, from the mesial surface of the mandibular first molar to the mesial surface of the lower left first molar (Fig 4). The brass wire was then straightened out, and with the aid of a steel millimeter ruler, the value for SA was ultimately obtained.

Finally, space analysis calculations were performed, the first using SA measurements obtained with the digital caliper [$TSALD = SA \text{ (caliper)} - SR$], and the second using the values obtained with the brass wire [$TSALD = SA \text{ (brass wire)} - SR$].

All measurements were performed by a single observer (T_1) previously trained. 20% of the models were measured again after 15 days (T_2) so as to test the operator's calibration.

Obtaining the digital model

Model scanning was performed with a 3Shape R700TM scanner (Copenhagen, Denmark). The de-

vice consists of a platform with support for the models, a laser and two digital cameras that capture high resolution images.

Scanning is performed with this equipment using a non-destructive laser beam which reproduces model surfaces so that the plaster model is not discarded.

First, the lower model was positioned on the platform so that the 3D scanner laser beam could map the desired profile. To this end, the platform is automatically rotated and inclined during scanning, thereby ensuring complete coverage of the object's geometry.

For the scanning process, it is necessary to start the ScanItOrthoImpression computer program and register the patients. Scanning is started after recording the patients' data and positioning the model on its base. During this process, the points on the plaster model are captured by the laser, thus rendering the virtual image. Images are obtained by organizing the points in a triangular form. The virtual image file is saved in DICOM format.

Once the model images are captured, 3Shape OrthoAnalyzer™ software (Copenhagen, Denmark) runs for manipulation of the digital model. Prior to model scanning, the scanner is calibrated with the aid of two tables which are attached to the scanner in order to standardize the measurements. This care was taken daily until the full digital sample was obtained.

Obtaining digital measurements

The digital models were measured with OrthoAnalyzer™ software. Initially, landmarks were plotted on the widest possible mesiodistal distance between teeth, starting from the second lower right premolar to the second lower left premolar, tooth after tooth, in order to record the SR values (Fig 5). Similarly to the manual method, SA measurements were performed using two different techniques: One using linear values, and one by forming a parabola.

Thus, linear values were used first in order to perform SA measurements. The procedure involved plotting the landmarks from the mesial surface of the mandibular right first molar to the mesial surface of lower right canine (Fig 6), and from the mesial surface of the canine to the region between central incisors (Fig 7). The same procedure was adopted for the opposite side, with plotting starting from the region between incisors.

In order to obtain SA values by means of a parabola, the parabola had to be formed in such a way as

to contour the occlusal surfaces of posterior teeth and incisal surfaces of anterior teeth (Fig 8).

Finally, two tooth size-arch length discrepancy calculations were performed. The first, using SA measurements obtained through linear measurements [$TSALD = SA \text{ (linear)} - SR$], and the second using the values obtained when shaping the parabola [$TSALD = SA \text{ (parabola)} - SR$].

All digital measurements as well as those obtained by the manual method were performed by a single observer previously trained (T_1). 20% of the models were measured again after 15 days (T_2) so as to test the operator's calibration.

STATISTICAL ANALYSIS

Intraclass correlation coefficient (ICC) statistic was performed using BioEstat 5.0 software to assess the operator's calibration. Once found, TSALD values were compiled into a spreadsheet and subjected to statistical analysis, whereas Kolmogorov-Smirnov test was applied to assess data normality. Furthermore, reliability between methods was tested by Friedman test using BioEstat version 5.0 software (Bélem, PA - Brazil).

RESULTS

Excellent reproducibility (0.98) of methods was found after intraclass correlation coefficient (ICC)

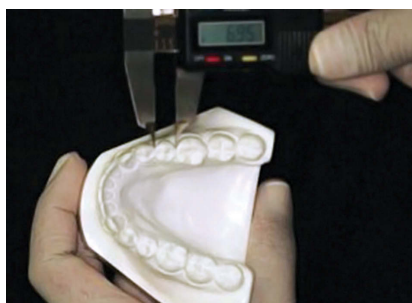


Figure 1 - Space Required – Measuring the mesiodistal width of second right premolar.

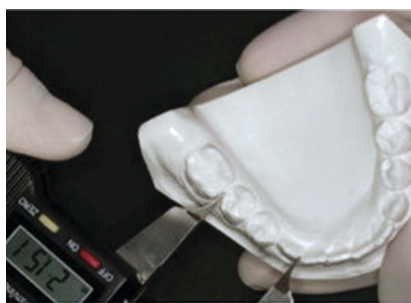


Figure 2 - Space Available – Caliper positioned from the mesial surface of first right molar to the mesial surface of right canine.



Figure 3 - Space Available – Caliper positioned from the mesial surface of right canine to the region between central incisors.



Figure 4 - Measuring Space Available with brass wire.



Figure 5 - Space Required – Measuring the mesiodistal width of second right premolar on the virtual model.

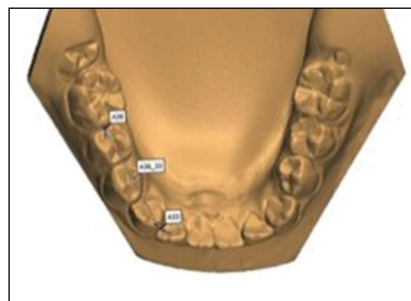


Figure 6 - Space Available – Landmarks plotted from the mesial surface of first right molar to the mesial surface of right canine on the virtual model.

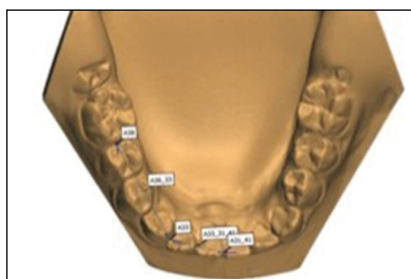


Figure 7 - Space Available – Landmarks plotted from the mesial surface of right canine to the region of central incisors on the virtual model

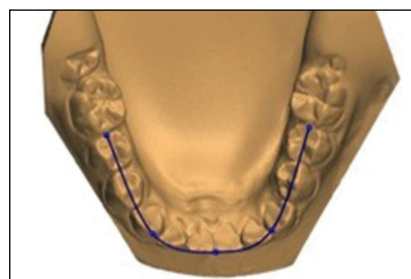


Figure 8 - Measuring Space Available on the virtual model with the aid of a parabola.

statistic, which is considered indicative of optimal agreement between measurements obtained at T_1 and T_2 with the operator duly calibrated for research.

Komogorov Smirnov statistical test confirmed the hypothesis of an abnormal distribution between T_1 and T_2 if the median and quartiles (25% and 75%) were employed as measures of variability (Table 1).

Friedman statistical test was performed to assess method reliability, which showed (at a significance level of $P \leq 0.05$) that the differences between measurements were not statistically significant, except for the values found by the linear digital method (Fig 9) which revealed a slight, non-significant statistical difference. This finding also allows one to assert that these methods, used by orthodontists in their professional life to obtain tooth-size discrepancy, can be considered reliable.

DISCUSSION

Given the remarkable development of computer science, which arises increased interest in 3D images among orthodontists, a number of companies currently offers services to transform plaster casts into three-dimensional digital models.^{1,3,8,14,20}

This method has several advantages, namely: reduced physical space, averting the risk of breakage, easy data storage, simultaneous exchange of information with colleagues, and greater efficiency and productivity in dental practice.^{6,15-22}

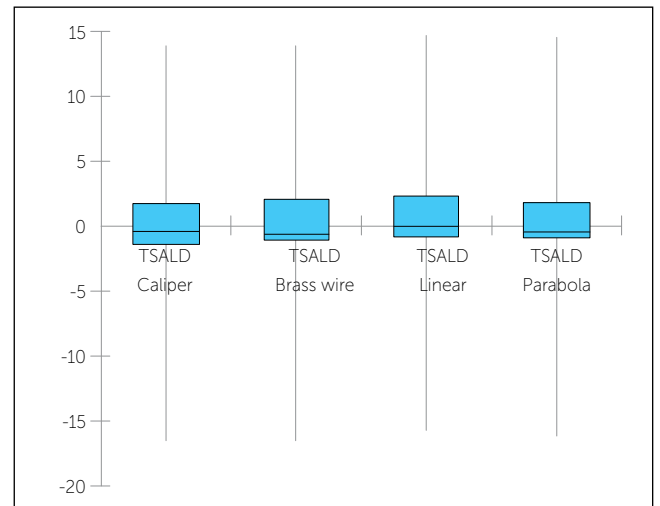
However, despite all these advantages, the exclusive use of digital models in daily practice is not yet routine as it also features some disadvantages in its application, namely: data loss in case of degradation of electronic storage, dependence on third parties, time-consuming software support, need to learn the operating system, and high cost of equipment.^{6,21}

Faced with these new technologies, some authors have assessed the reliability of these new methods. Alcan et al²³ and Sousa et al²⁴ conducted a research to assess the reliability of measurements performed on digital models obtained with a D250 scanner, manufactured by 3Shape. The authors found no statistically significant difference between measurements obtained directly on the plaster models *versus* the digital models. They concluded, therefore, that digital models can be used in orthodontic practice thanks to their accuracy and reproducibility.

Table 1 - Values of medians and 25% and 75% interquartile interval values.

	Method	25%	Median	75%
Manual	TSALD caliper	-1.48	-0.41	1.89
	TSALD brass wire	-1.40	-0.60	2.44
Digital	TSALD linear	-0.88	-0.15	2.52
	TSALD parabola	-1.02	-0.38	2.07

Figure 9 - Box plot with median values of the four different methods used to obtain tooth size-arch length discrepancy.



Leifert et al²⁵ assessed SA and SR measurements on dental casts using a digital caliper and brass wire, and on three-dimensional digital models using OrthoCad software. They observed that scanning accuracy required for spatial analysis on digital models is clinically acceptable and reproducible when compared with traditional plaster model analysis. These results agree with those of the present study, since there was no difference between manual and digital methods, although OrthoAnalyzer™ software was employed to obtain digital measurements.

Grehs²⁶ assessed the accuracy and reproducibility of tooth size and interdental measurements taken on plaster *versus* digital models scanned with a 3Shape R-700™ Scanner. A digital caliper was used for the manual measurements whereas O3d (Widialabs) software was used for the digital measurements. Results revealed that both the caliper and the O3d software had similar performance in enabling measurements and analyses. Although research assessed

different measurements, the results agree with those of the present study, as it became clear from the methodology developed herein that there is similarity between measurements obtained manually and digitally.

Further corroborating these results, the investigation conducted by Zilberman et al,⁵ Quimby et al¹ and Bootvong et al²⁷ compared plaster and digital (OrthoCad) models, and showed that both methods are effective and can be reproduced when measuring tooth size and dental arch widths. Quimby et al¹ also suggested that features such as convenient storage and shorter time required for measuring with the digital system are likely to render this method attractive for orthodontists.

However, Garino and Garino¹⁷ found statistically significant differences between measurements obtained with digital *versus* plaster models using OrthoCad software, thereby disagreeing with the results of this study which found that both digital and manual measurements are just as reliable. Furthermore, it is noteworthy that the authors cited above used an analog caliper with 0.5 mm precision to obtain the manual measurements and an instrument with 0.1 mm precision to perform the digital measurements, which discloses the limitations of measuring a manual analog method. In addition, tooth position such as inclination, rotation and crowding, may have influenced the measurements,

thus showing significant differences, especially in plotting mesiodistal landmarks.

Research by Santoro et al⁶ also found statistically significant differences in comparing overbite and tooth size values using manual *versus* digital (OrthoCAD) methods. The authors found that digital measurements were smaller than manual measurements, and explained that the differences were probably due to an intrinsic difference between methods, such as the ability to enlarge the image to better observe the mesiodistal diameters provided by the digital method. The values, however, were not considered clinically significant.

CONCLUSIONS

Based on the results it is reasonable to conclude that Tooth Size-Arch Length Discrepancy values found by manual (Cen-Tech digital caliper and 4-in brass wire) *versus* digital (3Shape R-700TM / 3Shape OrthoAnalyzerTM) methods did not differ, except for the values found by the linear digital method. The latter revealed a slight, non-significant statistical difference, thereby confirming that any of these resources used by orthodontists to clinically obtain Tooth Size-Arch Length Discrepancy can be considered as reliable methods.

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In vitro study of color stability of polycrystalline and monocrystalline ceramic brackets

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Objective: The aim of this *in vitro* study was to analyze color stability of monocrystalline and polycrystalline ceramic brackets after immersion in dye solutions.

Methods: Seven ceramic brackets of four commercial brands were tested: Two monocrystalline and two polycrystalline. The brackets were immersed in four dye solutions (coffee, red wine, Coke and black tea) and in artificial saliva for the following times: 24 hours, 7, 14 and 21 days, respectively. Color changes were measured by a spectrophotometer. Data were assessed by Multivariate Profile Analysis, Analysis of Variance (ANOVA) and Multiple Comparison Tests of means.

Results: There was a perceptible change of color in all ceramic brackets immersed in coffee (ΔE^* Allure = 7.61, Inspire Ice = 6.09, Radiance = 6.69, Transcend = 7.44), black tea (ΔE^* Allure = 6.24, Inspire Ice = 5.21, Radiance = 6.51, Transcend = 6.14) and red wine (ΔE^* Allure = 6.49, Inspire Ice = 4.76, Radiance = 5.19, Transcend = 5.64), but no change was noticed in Coke and artificial saliva ($\Delta E < 3.7$).

Conclusion: Ceramic brackets undergo color change when exposed to solutions of coffee, black tea and red wine. However, the same crystalline structure, either monocrystalline or polycrystalline, do not follow the same or a similar pattern in color change, varying according to the bracket fabrication, which shows a lack of standardization in the manufacturing process. Coffee dye produced the most marked color changes after 21 days of immersion for most ceramic brackets evaluated.

Keywords: Color. Ceramics. Orthodontic brackets.

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INTRODUCTION

The first esthetic brackets appeared in the 70's and were made from polycarbonate, a plastic material. Although these brackets were reasonably esthetic, this material did not present suitable properties for clinical use. Several studies showed clinical problems such as deformation and structural weakness, poor adhesion and poor stain resistance during treatment.^{1,2,3}

In the mid-1980s, other types of material were tested to meet the esthetic needs of the orthodontic market, and that was when esthetic ceramic brackets appeared. These brackets are mainly made from aluminum oxide and are available in two forms according to the manufacturing process: polycrystalline or monocrystalline.^{4,5}

Polycrystalline or alumina polycrystalline brackets are made of aluminum oxide crystals fused at high temperatures (near 1950°C).⁶ Monocrystalline brackets are made of a single crystal produced from the combination of particles of aluminum oxide fused at a higher temperature (2100°C) and cooled slowly, thus enabling thorough control of crystallization.^{4,7}

Thus, the manufacturing process produces translucent and nontranslucent ceramic brackets. Monocrystalline brackets are included in the translucent brackets group while polycrystalline brackets are nontranslucent.⁸ The translucency of monocrystalline brackets is due to the structure of a single crystal that provides passage of light. Polycrystalline brackets are not translucent because their structure presents lack of boundaries between the crystals and impurities incorporated during the manufacturing process, thereby hindering passage of light.⁹

To have a good esthetic appearance, nontranslucent brackets need to be similar in color and fluorescence to the underlying tooth, whereas translucent brackets need to have sufficient translucency so as to allow the color and fluorescence of the tooth to pass through them. However, it is essential that both have good color stability.⁸

Even if esthetics is the only advantage of ceramic brackets in relation to metal brackets, they are not color stable in the long term. As reported by some authors, the color of these accessories changes in the oral environment due to staining from substances containing pigments commonly found in food and drinks.^{3,6,10,11,12}

Nevertheless, only a few studies have been conducted to investigate the color changes and the factors that lead to such changes. Therefore, this study aims to analyze *in vitro* the color stability of monocrystalline

and polycrystalline esthetic ceramic brackets after immersion in dye solutions commonly present in food and drinks in order to know if the crystal structure of these brackets follow a similar pattern of color change.

MATERIAL AND METHODS

The sample comprised maxillary right central incisors ceramic brackets, slot size 0.022 x 0.028-in in Roth prescription. Four commercial brands were selected: Two brands were monocrystalline brackets — Inspire Ice from Ormco® (Orange, California) and Radiance from American Orthodontics® (Sheboygan, Wisconsin); and two were polycrystalline brackets — Allure MB from GAC® (Bohemia, New York) and Transcend from 3M Unitek® (Monrovia, California). To prevent the glue surfaces of different brands from interfering in the staining process, all surfaces were worn with a diamond drill bit. Seven brackets of each brand were tested.

The brackets were immersed in solutions of coffee, dry red wine, Coke, black tea and artificial saliva (control group) (Table 1). Each one of these solutions was distributed into glass chambers with partitions to separate the different brands of brackets. These containers were placed in an incubator at a temperature of 37°C wrapped in black plastic bags to eliminate the interference of light. The solutions were changed every 24 hours and their pH was measured with a pH meter (Model 8010, Qualxtron) at each change to check whether it remained the same.

The color parameters of brackets were measured at the following times: T_0 (initial measurement), T_1 , T_2 , T_3 and T_4 (brackets immersed in dye solution for 24 hours, 7, 14 and 21 days, respectively). Before each color reading, brackets were washed with distilled water and blotted dried to remove any residual waste from the dyes on the brackets.

Color measurements of each group of brackets were obtained using a portable reflectance spectrophotometer Spectro-guide (Byk Gardner®, Columbia, USA). Spectro-guide measures the intensity of each wavelength of light reflected by the sample when illuminated by a polychromatic light (illuminant D65) emitted from the device at an angle of 45°. Light reflected from the sample is captured by a viewing angle of 0°. The measuring aperture diameter size was 3 mm. Tristimulus values (L^* , a^* and b^*) were supplied by the device from the captured light.

Table 1 - Solutions, brands, pH values and preparation methods.

Solution	pH	Brand	Preparation
Coffee	5	Nescafé (Nestlé, Brazil Ltda, Brazil)	Solution prepared with 50 g of instant coffee added to 200 ml of boiling distilled water.
Red wine	3.3	Dry red wine (Canção - Serra Gaúcha, Rio Grande do Sul, Brazil)	Solution ready for consumption
Black tea	5.2	Black tea sachet (Leão Junior S.A., Brazil)	Solution prepared with one black tea sachet immersed in 200 ml of boiling distilled water
Coke	2.4	Coke (Coca-Cola Co.)	Solution ready for consumption
Artificial saliva	7	Artificial saliva (Farmácia Santa Paula - Araraquara, São Paulo, Brazil).	Prepared solution (neutral pH, tasteless and odorless)

* All solutions were distributed into containers at ambient temperature.

Potential color changes of brackets were measured in accordance with the Commission Internationale de l'Eclairage (CIE) L^* , a^* , b^* (LAB) color scale.¹³ This color measurement system¹⁴ quantitatively determines color by using three parameters (L^* , a^* and b^*). On the CIELAB color scale, L^* is a measure of brightness of an object. It is quantified on a scale in which black has a L^* value of zero; and light, which is totally reflected, has a L^* value of 100. On the same scale, a^* accounts for the amount of red (+ a^*) and green (- a^*), whereas b^* accounts for the amount of yellow (+ b^*) and blue (- b^*). Color change (ΔE^*) was calculated using the equation: $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. Changes in color parameters ΔL^* , Δa^* and Δb^* were obtained by subtracting the final values from the baseline (T_0).

For color measurements, brackets were positioned in a matrix of white silicone rubber from Redelease® (4 matrices were made for the four brands of brackets) coupled to a positioner where the spectrophotometer was embedded. Thus, the brackets and the spectrophotometer were always in the same position for all measurements.

Statistical analysis

To evaluate the error of the method, two measurements were made for each variable. Reproducibility was assessed by means of the Intraclass Correlation Coefficient (ICC).

Multivariate Profile Analysis, carried out by means of the Pillai Trace test, was used to evaluate the effect of time.

Analysis of Variance (ANOVA) with one classification criterion and Bonferroni Test of Multiple Comparison of means were used to define any statistical difference of color change between brands and between solutions. These analyses were preceded by a test of homogeneity of variances. Should homogeneity of variances be rejected, ANOVA was replaced by Brown-Forshyte test and the Multiple Comparison Tests of means was conducted with the Tamhane test.

The statistical software SPSS version 16.0 (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA) was used to tabulate and analyze data. Statistical significance was adopted at 95% confidence interval.

RESULTS

Results of intraclass correlation coefficients (ICC) revealed that the method for measuring the color of ceramic brackets was effective. A high degree of reproducibility as obtained for all parameters of color (L^* , a^* , b^*), thus indicating a negligible method error (range limit top and bottom of the ICC: 0.8 to 1.00).

Table 2 presents the results of the multivariate tests for assessing color change over time. Results show that

color of ceramic brackets changes over time. Furthermore, there is no similarity of color change over time among all brackets. A significant difference in bracket staining between solutions was also observed over immersion time. Thus, color change over time depends on a brand-solution combination.

Comparative study of ceramic brackets staining by solution and immersion time

Bracket brands (two monocrystalline and two polycrystalline) were assessed for color change produced by each solution within each time period. Results are shown in Table 3 and Figure 1.

Table 2 - Pillai trace multivariate test for significance of color change. Intra individual factor = time.

Effect	Pillai trace	F test				Power
		F	df1	df2	p	
Time	0.945	1419.643	3	250	<0.001	> 0.999
Time * brand	0.776	29.296	9	756	<0.001	> 0.999
Time * solution	1.441	58.208	12	756	<0.001	> 0.999
Time * brand * solution	0.56	4.816	36	756	<0.001	> 0.999

Note: df1 = numerator degrees of freedom; df2 = denominator degrees of freedom.

Table 3 - Mean and standard deviation of color change (ΔE^*) of ceramic brackets in each solution and time, result of the Variance Analysis and multiple comparison of means.

Time of immersion	ALLURE	INSPIRE ICE	RADIANCE	TRANSCEND	ANOVA	
	ΔE^* Mean $\pm$ SD	ΔE^* Mean $\pm$ SD	ΔE^* Mean $\pm$ SD	ΔE^* Mean $\pm$ SD	F	P
ARTIFICIAL SALIVA						
24 hours	1.26 ^A $\pm$ 0.20	1.07 ^{AB} $\pm$ 0.13	0.81 ^B $\pm$ 0.47	0.29 ^C $\pm$ 0.14	16.79	0.000
7 days	1.27 ^A $\pm$ 0.27	1.10 ^A $\pm$ 0.32	1.68 ^B $\pm$ 0.48	0.41 ^C $\pm$ 0.09	19.35	0.000
14 days	1.43 ^A $\pm$ 0.29	1.06 ^A $\pm$ 0.12	1.37 ^A $\pm$ 0.40	0.44 ^B $\pm$ 0.17	20.09	0.000
21 days	1.45 ^A $\pm$ 0.30	0.46 ^B $\pm$ 0.10	1.82 ^C $\pm$ 0.30	0.64 ^B $\pm$ 0.17	53.58	0.000
COKE						
24 hours*	1.40 ^A $\pm$ 0.21	2.22 ^B $\pm$ 0.10	1.29 ^A $\pm$ 0.14	1.65 ^{AB} $\pm$ 0.78	7.01	0.014
7 days	2.43 ^A $\pm$ 0.20	2.02 ^B $\pm$ 0.21	2.29 ^{AB} $\pm$ 0.13	1.53 ^C $\pm$ 0.30	23.03	0.000
14 days	2.50 ^A $\pm$ 0.33	2.13 ^{BC} $\pm$ 0.19	2.43 ^{AC} $\pm$ 0.18	1.89 ^B $\pm$ 0.13	11.11	0.000
21 days	2.63 ^A $\pm$ 0.21	2.02 ^B $\pm$ 0.25	2.48 ^A $\pm$ 0.18	1.89 ^B $\pm$ 0.18	20.61	0.000
COFFEE						
24 hours	2.28 $\pm$ 0.27	2.44 $\pm$ 0.18	2.16 $\pm$ 0.34	2.47 $\pm$ 0.24	2.14	0.126
7 days	5.16 ^A $\pm$ 0.48	3.57 ^B $\pm$ 0.34	5.33 ^A $\pm$ 0.30	5.05 ^A $\pm$ 0.23	37.75	0.000
14 days	5.47 ^A $\pm$ 0.32	4.97 ^B $\pm$ 0.37	5.91 ^A $\pm$ 0.34	5.94 ^A $\pm$ 0.22	14.44	0.000
21 days	7.61 ^A $\pm$ 0.44	6.09 ^B $\pm$ 0.38	6.69 ^C $\pm$ 0.42	7.44 ^A $\pm$ 0.31	22.59	0.000
BLACK TEA						
24 hours	0.99 ^A $\pm$ 0.24	1.74 ^B $\pm$ 0.22	1.27 ^A $\pm$ 0.25	1.19 ^A $\pm$ 0.15	14.84	0.000
7 days	3.23 ^A $\pm$ 0.34	2.17 ^B $\pm$ 0.20	3.51 ^A $\pm$ 0.24	3.15 ^A $\pm$ 0.13	41.09	0.000
14 days	4.77 ^A $\pm$ 0.23	4.29 ^B $\pm$ 0.28	5.44 ^C $\pm$ 0.24	4.73 ^A $\pm$ 0.30	22.72	0.000
21 days	6.24 ^A $\pm$ 0.39	5.21 ^B $\pm$ 0.38	6.51 ^A $\pm$ 0.20	6.14 ^A $\pm$ 0.39	18.42	0.000
RED WINE						
24 hours*	3.07 ^A $\pm$ 0.51	3.62 ^A $\pm$ 0.27	1.83 ^B $\pm$ 0.27	2.04 ^B $\pm$ 0.14	47.30	0.000
7 days	5.21 ^A $\pm$ 0.44	3.63 ^B $\pm$ 0.39	4.24 ^C $\pm$ 0.43	3.50 ^B $\pm$ 0.24	28.84	0.000
14 days	5.76 ^A $\pm$ 0.33	4.53 ^B $\pm$ 0.57	5.26 ^{AC} $\pm$ 0.21	4.91 ^{BC} $\pm$ 0.29	13.67	0.000
21 days	6.49 ^A $\pm$ 0.47	4.76 ^B $\pm$ 0.69	5.19 ^{BC} $\pm$ 0.31	5.64 ^C $\pm$ 0.33	16.94	0.000

Notes: 1) In times marked with a *, brands are not equal. In this case, ANOVA was replaced by Brown-Forsythe test. 2) Same letters account for statistically similar means. Letters are not displayed when the result of ANOVA was not significant or when multiple comparison of means was not able to detect different means.

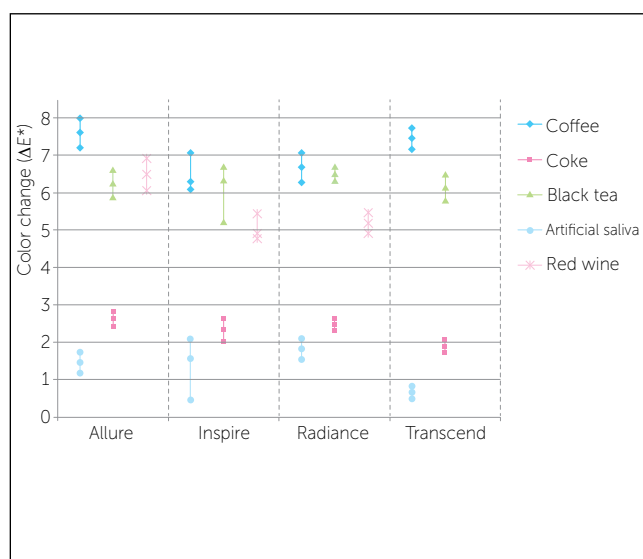


Figure 1 - Mean values and 95% confidence intervals of color change by brand in coffee, black tea, red wine, Coke and artificial saliva solutions.

There was an overall pattern of increasing color change for all brands. However, brackets with the same crystal formation do not follow the same or similar patterns in terms of color change. In other words, monocrystalline or polycrystalline structures do not interfere in how brackets are stained. Furthermore, Inspire Ice bracket had the lowest color change mean after 21 days.

Comparative study of dye solutions for color change produced on brackets within each immersion time.

In this analysis, solutions were compared for color changes produced on brackets of each brand tested within each time period, as shown in Table 4.

Color change was considered clinically significant only for values of $\Delta E^* > 3.7$.^{15,16,17} Thus, artificial saliva and Coke solutions did not produce major changes

Table 4 - Mean and standard deviation of color change (ΔE^*) produced by solutions on ceramic brackets over time; result of Variance Analysis and multiple comparison of means.

Time of immersion	ARTIFICIAL SALIVA	COKE	COFFEE	BLACK TEA	RED WINE	ANOVA	
	ΔE^* Mean $\pm$ SD	ΔE^* Mean $\pm$ SD	ΔE^* Mean $\pm$ SD	ΔE^* Mean $\pm$ SD	ΔE^* Mean $\pm$ SD	F	P
ALLURE							
24 hours	1.26 ^a $\pm$ 0.2	1.4 ^a $\pm$ 0.21	2.28 ^a $\pm$ 0.27	0.99 ^a $\pm$ 0.24	3.07 ^b $\pm$ 0.51	53.53	0.000
7 days	1.27 ^a $\pm$ 0.27	2.43 ^b $\pm$ 0.2	5.16 ^c $\pm$ 0.48	3.23 ^b $\pm$ 0.34	5.21 ^c $\pm$ 0.44	158.86	0.000
14 days*	1.43 ^a $\pm$ 0.29	2.5 ^b $\pm$ 0.33	5.47 ^c $\pm$ 0.32	4.77 ^b $\pm$ 0.23	5.76 ^c $\pm$ 0.33	280.48	0.000
21 days	1.45 ^a $\pm$ 0.3	2.63 ^b $\pm$ 0.21	7.61 ^c $\pm$ 0.44	6.24 ^b $\pm$ 0.39	6.49 ^b $\pm$ 0.47	359.29	0.000
INSPIRE ICE							
24 hours	1.07 ^a $\pm$ 0.13	2.22 ^b $\pm$ 0.1	2.44 ^b $\pm$ 0.18	1.74 ^c $\pm$ 0.22	3.62 ^b $\pm$ 0.27	173.66	0.000
7 days*	1.1 ^a $\pm$ 0.32	2.02 ^b $\pm$ 0.21	3.57 ^c $\pm$ 0.34	2.17 ^b $\pm$ 0.2	3.63 ^c $\pm$ 0.39	90.93	0.000
14 days*	1.06 ^a $\pm$ 0.12	2.13 ^b $\pm$ 0.19	4.97 ^c $\pm$ 0.37	4.29 ^b $\pm$ 0.28	4.53 ^{cd} $\pm$ 0.57	173.26	0.000
21 days	0.46 ^a $\pm$ 0.1	2.02 ^b $\pm$ 0.25	6.09 ^c $\pm$ 0.38	5.21 ^b $\pm$ 0.38	4.76 ^b $\pm$ 0.69	233.33	0.000
RADIANCE							
24 hours	0.81 ^a $\pm$ 0.47	1.29 ^{bcd} $\pm$ 0.14	2.16 ^b $\pm$ 0.34	1.27 ^c $\pm$ 0.25	1.83 ^b $\pm$ 0.27	33.9	0.000
7 days	1.68 ^a $\pm$ 0.48	2.29 ^b $\pm$ 0.13	5.33 ^c $\pm$ 0.3	3.51 ^b $\pm$ 0.24	4.24 ^e $\pm$ 0.43	497.23	0.000
14 days	1.37 ^a $\pm$ 0.4	2.43 ^b $\pm$ 0.18	5.91 ^c $\pm$ 0.34	5.44 ^b $\pm$ 0.24	5.26 ^b $\pm$ 0.21	706.24	0.000
21 days*	1.82 ^a $\pm$ 0.3	2.48 ^b $\pm$ 0.18	6.69 ^c $\pm$ 0.42	6.51 ^b $\pm$ 0.2	5.19 ^e $\pm$ 0.31	713.58	0.000
TRANSCEND							
24 hours	0.29 ^a $\pm$ 0.14	1.65 ^a $\pm$ 0.78	2.47 ^b $\pm$ 0.24	1.19 ^a $\pm$ 0.15	2.04 ^b $\pm$ 0.14	19.64	0.000
7 days*	0.41 ^a $\pm$ 0.09	1.53 ^b $\pm$ 0.3	5.05 ^c $\pm$ 0.23	3.15 ^b $\pm$ 0.13	3.5 ^e $\pm$ 0.24	131.54	0.000
14 days	0.44 ^a $\pm$ 0.17	1.89 ^b $\pm$ 0.13	5.94 ^c $\pm$ 0.22	4.73 ^b $\pm$ 0.3	4.91 ^b $\pm$ 0.29	358.04	0.000
21 days	0.64 ^a $\pm$ 0.17	1.89 ^b $\pm$ 0.18	7.44 ^c $\pm$ 0.31	6.14 ^c $\pm$ 0.39	5.64 ^b $\pm$ 0.33	415.68	0.000

Note: 1) In times marked with a *, brands are not equal. In this case ANOVA was replaced by Brown-Forsythe test. 2) Same letters account for statistically similar means. Letters are not displayed when the result of ANOVA was not significant or when multiple comparison of means was not able to detect different means.

distinguished by the naked eye. Conversely, coffee, black tea and red wine promoted visible changes, in general, from the 14th day of immersion on.

Coffee dye solution produced the most marked color changes after 21 days of immersion for most brackets, except for Transcend brackets that, despite having the highest average, were statistically similar to black tea.

DISCUSSION

The results of this study led to the conclusion that all ceramic brackets change in color. However, brackets with the same crystal formation did not follow the same or similar patterns of color change when exposed to the same dye solutions under the same conditions. Thus, the degree of staining was different in several brands, and monocrystalline or polycrystalline structure did not affect staining, thereby showing that esthetic behavior depends on the bracket manufacturer.

In the literature, there are few studies about color changes of different esthetic ceramic brackets after immersion in dye solutions. According to them,¹⁶⁻¹⁹ the color of ceramic brackets changes over time when exposed to potentially dye solutions commonly present in people's diet. In addition, staining is cumulative, it increases as the time of exposure to the coloring elements increases. Nevertheless, only a few studies were comparable with the results of this study, given that most of them compare ceramic and plastic brackets.

Among them, a recent work¹⁹ obtained similar findings to our study. The authors confirmed that the crystal structure of ceramic brackets has no effect on staining. This conclusion was obtained after confirming that Inspire Ice and Radiance, two monocrystalline brackets, had the lowest and highest values of color change, respectively.

Other authors²⁰ are in agreement with these findings. They report that brackets with the same composition made by different manufacturers had different behaviors in color change. This shows a discrepancy in the manufacturing process of brackets and its influence on their esthetic performance.

Only one research¹⁶ yielded opposite results. According to the authors, color stability of monocrystalline and polycrystalline ceramic brackets remained statistically equal after 14 days. Nevertheless, color was measured at the base brackets worn by drill, thereby not corresponding to the actual surface area exposed to the

oral environment or to the entire surface conditions produced by the manufacturer.

According to Yu and Lee,²⁰ variation in staining between brackets with the same crystalline formation can be explained by lack of evidence proving that brackets classified within the same composition category, but made by different manufacturers, are actually made of the same material. Moreover, they also raised the possibility that size, shape and roughness could be the cause of this divergence in the optical properties of ceramic brackets. Lee¹⁵ corroborates the aforementioned work by asserting that bracket surface, size and type of accessories may influence color stability. He also suggests that further studies on the influence of surface on color stability be conducted in order to yield results that can be used to develop esthetic brackets with improved color stability. However, there is no scientific evidence supporting these theories.

For the present study, Inspire Ice bracket had the lowest mean value of color change in most solutions. However, there was a variation in staining, depending on the interaction between the bracket brand and solution. For this reason, we cannot determine which bracket has the best or worst color stability. These results confirm previous studies^{16,19,20} that assessed staining of ceramic brackets and also found many levels of staining, depending on the solution assessed.

The clinical relevance of color changes in the ceramic brackets should also be addressed in terms of dye potential. For Cosmetic Dentistry, color change greater than 2 is already visible for all observers.²¹ Nevertheless, we adopted a parameter of 3.7. This value is based on the limits of color change that are clinically visible and used in studies with ceramic fac-ets²² and esthetic brackets.^{15,16}

Considering the value of $\Delta E^* > 3.7$ as clinically significant staining, artificial saliva and Coke did not produce color changes that were perceptible to the naked eye. Conversely, coffee, black tea and red wine produced visible changes ($\Delta E^* > 3.7$) from the 14th day of immersion on. Coffee solution produced the most marked color changes for all brackets after 21 days of immersion, except for Transcend brackets that, despite having the highest mean value, were statistically similar to black tea.

Our results are in agreement with a previous study¹⁷ that showed that mean values above 3.7 were obtained for Transcend and INVU ceramic brackets immersed in coffee solution after 14 days. Artificial saliva did not visibly alter the color of these brackets.

Different values of perceptible color changes were used in a different study¹⁸ which assert that the range of $5 < \Delta E^* < 10$ is noticeable. The authors also claim that mean values greater than 10 account for indisputable discoloration of brackets. Thus, they concluded that all brackets immersed in black tea, coffee or red wine showed similar reactions with a marked increase in discoloration after 5 days. This study corroborates our results; however, with a staining power achieved within a shorter period of time, since, after 24 hours, color change was observed with $\Delta E^* > 3.7$ for all brackets.

Divergent results were found in another study¹⁶ in which color change values were below clinically significant values ($\Delta E^* > 3.7$) for all brackets in all solutions. However, these values cannot be compared to other studies, since their spectrophotometric evaluation was performed on the base of worn brackets, unlike most studies that measured color on the vestibular surface of these accessories.

It has been shown that even though Coke has a lower pH value that can damage surface integrity of material, it does not promote clinically significant color changes like coffee and black tea do, possibly due to lack of yellow dye in its constitution.²³ Coffee and tea have yellow dye, but with different polarities, which differs in their interaction with material surface. Park et al²⁴ also showed that pH was not the main element responsible for color changes. According to the authors, the amount and type of pigment was the main reason, thereby confirming the previous study. Studies on color change and ceramic brackets do not usually investigate the physical and chemical interaction between dye solutions and material components. For this reason, additional studies are warranted to further investigate this topic.

By comparing the *in vitro* results of this study with the clinical practice, some limitations are encountered, namely: Complex flora of the oral cavity and its by-products, as well as the buildup of biofilm on tested material.²⁵ Therefore, the present study as well as other *in vitro* studies showed overestimated values of color change. Since no *in vivo* studies have been conducted to demonstrate the real-time parameters for visible

color changes, additional studies are warranted to further investigate this topic.

Nevertheless, *in vitro* studies may provide an initial estimate. This estimate was calculated on the basis of a research²⁶ in which, according to coffee producers, the average time spent to consume a cup of coffee is 15 minutes and the average number of cups of coffee consumed per day is 3.2 cups. Therefore, 24 hours of immersion in coffee represents a monthly consumption of coffee. Thus, 21 days of immersion *in vitro*, as used in this study, simulates the susceptibility of ceramic brackets to coffee staining within 1 year and 9 months of orthodontic treatment.

This calculation can be individualized for each person, thereby allowing the risk of color change to be estimated according to orthodontic treatment time expected by the orthodontist and information on average color change provided by *in vitro* studies.

Akyalcin et al¹⁹ conducted an *in vitro* study to reproduce the exposure time necessary for a dye drink to act on brackets inside the mouth. The total time of the experiment was 26 weeks (equivalent to 6 months), with daily exposures of 10 minutes alternated by baths of water at 37°C. The amount of bracket exposure to dye solution differed according to the frequency of use of each drink, as limited by the authors. A total time ranging from 13 to 60 hours of exposure was used for the entire study period.

In any *in vitro* study, the biggest challenge is to reproduce the real conditions of the oral cavity. Under the conditions of our study, we are not able to provide the real time of bracket staining. Nevertheless, bracket structures should be improved by manufacturers in order to increase color stability and standardize the production process of these accessories. To this end, additional research about the possible factors that might promote color change of esthetic brackets is necessary, since the mechanism of staining is not clear in the literature.

CONCLUSION

The methodology of this study let us to conclude that ceramic brackets undergo color change when exposed to solutions of coffee, black tea and red wine, drinks commonly present in people's diet. However, the same crystalline structure, either monocrystalline or polycrystalline, do not follow the same or a similar pattern in color change, but vary from manufacturer to manufacturer;

thereby showing lack of standardization in the manufacturing process of these brackets. Coffee dye produced the most marked color changes after 21 days of immersion for most ceramic brackets assessed.

ACKNOWLEDGMENTS

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Two-phase treatment of patients with crossbite and tendency toward skeletal Class III malocclusion*



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Angle Class III malocclusion is characterized by an inadequate anteroposterior dental relationship which may or may not be accompanied by skeletal changes. In general, patients are distressed by a significantly compromised facial aspect which, when associated with a deficient middle third, encourages patients to seek treatment. This article reports a two-phase treatment carried out in a female patient aged six years and six months with a tendency towards a Class III skeletal pattern. This case was presented to the Brazilian Board of Orthodontics and Facial Orthopedics (BBO). It is representative of the Discrepancy Index (DI) category, and fulfills part of the requirements for obtaining BBO Diploma.

Keywords: Angle Class III malocclusion. Palatal expansion technique. Maxilla.

INTRODUCTION

This report describes the case of a healthy female patient presented for treatment at the age of six years and six months. Her medical and dental history was within the normal range, with no history of illness or trauma. She had good oral hygiene and saw her pedodontist every six months. Her parents' chief complaint was that her upper

teeth were positioned behind her lower teeth. The patient's father had Angle Class III malocclusion with a skeletal Class III pattern as well. Given that his daughter's dental arch resembled his own, he wanted her treatment to start as early as possible since he had been informed that in so doing she might avoid future surgery, or at least minimize it in case it was needed in adulthood.

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

*Clinical case report, DI 18, approved by the Brazilian Board of Orthodontics (BBO).

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

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DIAGNOSIS

Regarding her facial appearance, as shown in Figure 1, the patient had good symmetry, slightly convex profile, lip competence, slightly protruding lower lip and little exposure of upper incisors at speaking and smiling. Dental examination (Figs 1 and 2) revealed that the patient was in early mixed dentition with distal relationship of the primary molars in straight terminal plane while in the posterior region only tooth #16 had begun erupting. She presented with anteroposterior disharmony between maxilla and mandible, and maxillary constriction (atresia), resulting in a crossbite that extended from tooth #53 to #65. She also had a deep curve of Spee, 3.3 mm overbite and 4 mm negative overjet. A decrease in eruption spaces was also noted in teeth #12 and #22. The lower arch midline exhibited a 3.2 mm deviation, and there were spaces in the lower arch which produced a positive 5-mm discrepancy.

In analyzing the panoramic radiograph (Fig 3), it was observed that all permanent teeth were present, indicating that bone and tooth structures were within normal limits. Cephalometrically (Fig 4 and Tab 1), although the value of the ANB angle was within normal range ($ANB = 3.5^\circ$), it could be verified through Wits analysis ($Wits = -3 \text{ mm}$) that the patient had a skeletal pattern tending towards Class III. This fact, coupled with her unfavorable family history — given that the patient's father had a dental and skeletal Class III pattern — reinforced the need for early intervention. A growth pattern with vertical tendency ($SN-GoGn = 36^\circ$), severe axial inclination of upper incisors towards palatal ($1-NA = 0^\circ$), and well positioned lower incisors ($NB-1 = 26^\circ$) were also observed. It is noteworthy that mandibular manipulation caused no change from centric relation to maximum and habitual intercuspation (MHI). In calculating the Discrepancy Index (DI) a total of 18 points (Fig 5) was found.



Figure 1 - Initial facial and intraoral photographs.

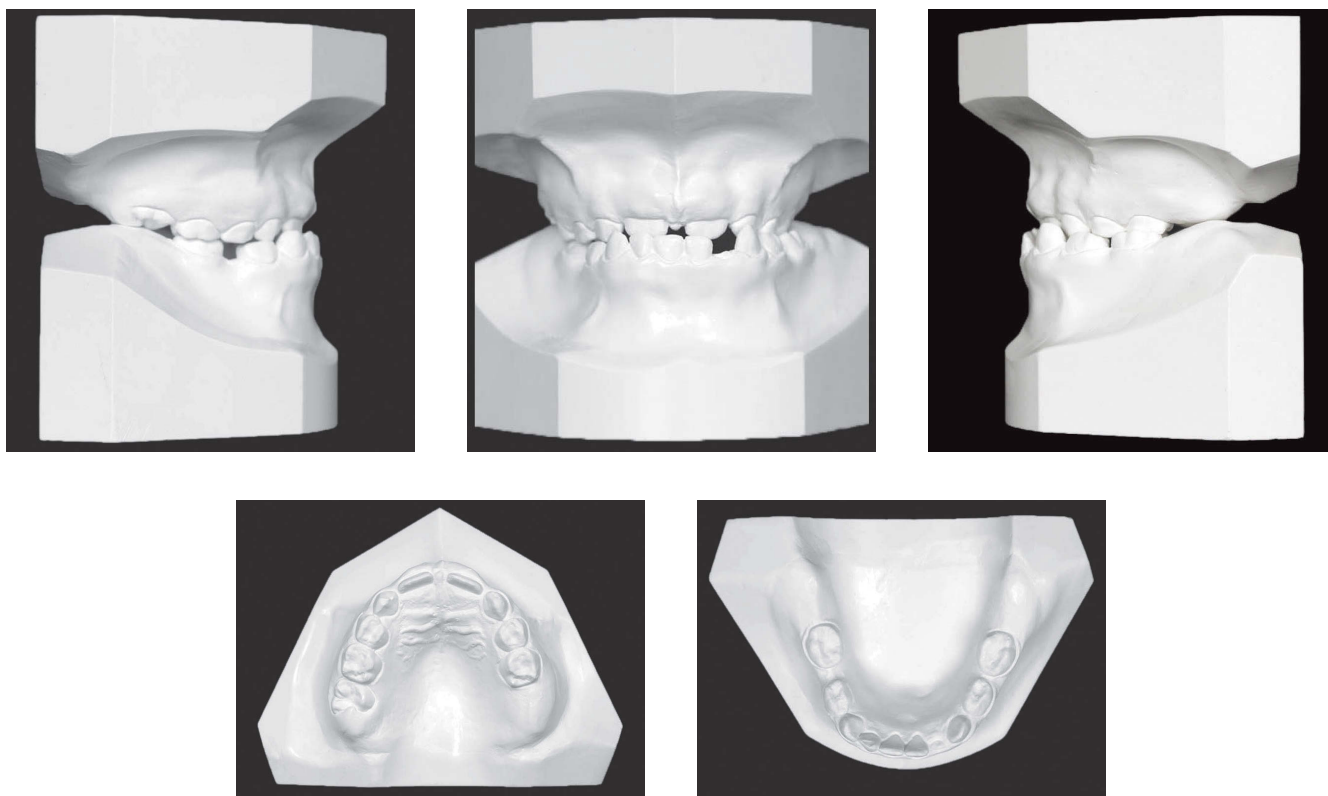


Figure 2 - Initial casts.

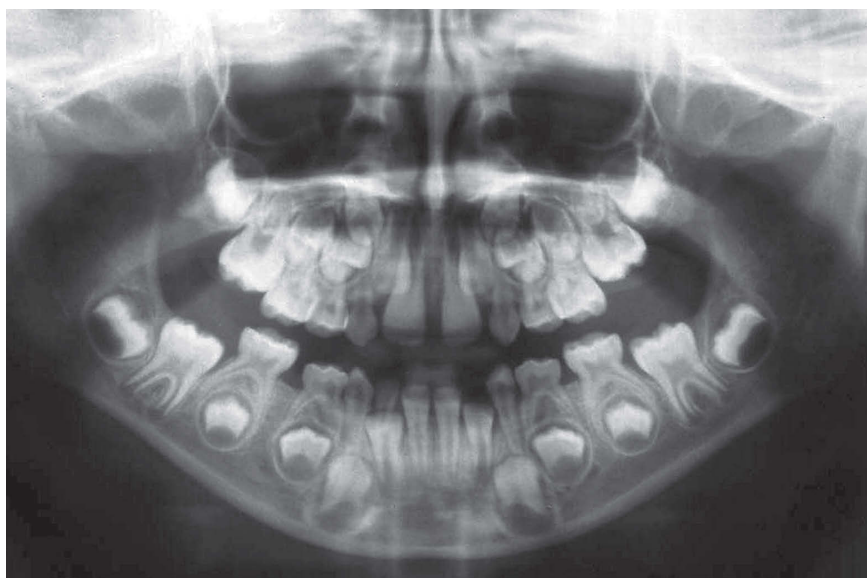


Figure 3 - Initial panoramic radiograph.

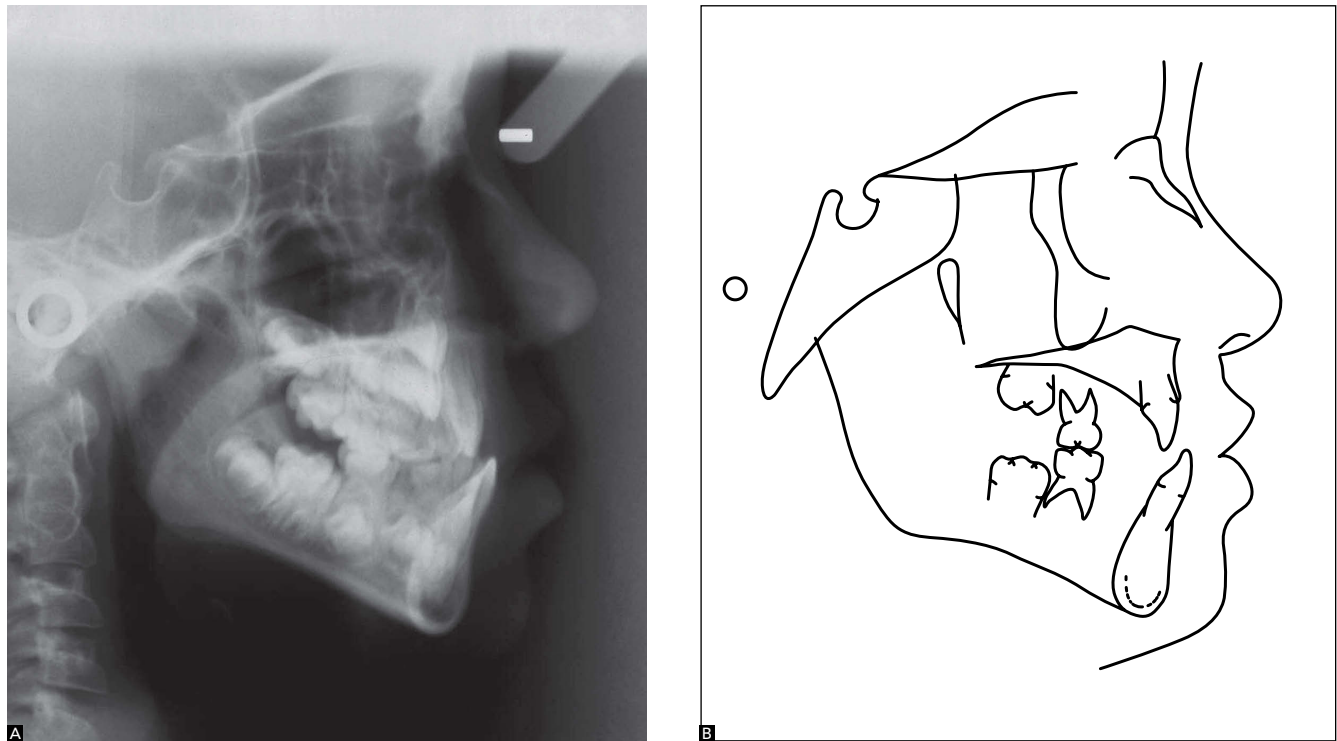


Figure 4 - Initial profile cephalometric radiograph (A) and cephalometric tracing (B).

TREATMENT PLAN (PHASE 1)

Planning involved a two-phase treatment. Initially, special attention would be given to the skeletal disharmony between maxilla and mandible which, if left uncorrected, would contribute significantly to the worsening of this condition during the whole process of growth and development of the bony bases. Thus, the anterior and posterior crossbites would be corrected, enlarging the maxilla in the transverse direction, thereby gaining space in the anterior region for proper eruption of teeth #12 and #22.

The patient and her parents would then be informed of the importance of compliance in wearing the appliances and the need to perform treatment in two phases. In this first phase, the patient was six years and six months old. The posterior crossbite would be corrected using a modified Haas palate expansion appliance supported on the second primary molars with acrylic covering the incisor surface of primary canines and occlusal surfaces of primary molars. Additionally, hooks would be soldered to the buccal surface of orthodontic bands fitted on second primary molars, combined with finger springs to procline teeth #11 and #21.

1- Overjet ≥ 0 to < 1 mm (edge-to-edge) = 1 point ≥ 1 to ≤ 3 mm = 0 point > 3 to ≤ 5 mm = 2 points > 5 to ≤ 7 mm = 3 points > 7 to ≤ 9 mm = 4 points > 9 mm = 5 points Negative = 1 pt/mm/tooth Total = 12		7- Lingual posterior crossbite buccal cusp > 0 mm to lingual = 1 point per maxillary tooth Total = 2	
2- Overbite > 0 to ≤ 3 mm = 0 point > 3 to ≤ 5 mm = 2 points > 5 to ≤ 7 mm = 3 points $> 100\%$ overbite = 5 points Total = 0		8- Buccal posterior crossbite palatal cusp > 0 mm to buccal = 2 points per maxillary tooth Total = 0	
3- Anterior open bite 0 mm (edge-to-edge) = 1 point/tooth Open bite (> 0 mm) = 1 point/add. mm/tooth Total = 0		9- Cephalometric measurements ANB $\geq 6^\circ$ or $\leq -2^\circ$ 4 points = 0 For each degree $> 6^\circ$ or $< -2^\circ$ + 1 point = 0 SN-MP $\geq 38^\circ$ 2 points = 0 For each degree $> 38^\circ$ + 2 point = 0 SN-MP $\leq 26^\circ$ 1 point = 0 For each degree $< 26^\circ$ + 1 point = 0 I to MP $\geq 99^\circ$ 1 point = 0 For each degree $> 99^\circ$ + 1 point = 0 Total = 0	
4- Lateral open bite ≥ 0.5 mm (maxillary posterior tooth) = 2 points/mm/tooth Total = 0		10- Other conditions Supernumerary 1 point/tooth = 0 Ankylosis of permanent teeth 2 points/tooth = 0 Anomalous morphology 2 points/tooth = 0 Impaction (except for 3 rd molars) 2 points/tooth = 0 Midline discrepancy ≥ 3 mm 2 points = 0 Missing teeth (except 3 rd molars) » Non-congenital 1 point/tooth = 0 » Congenital 2 points/tooth = 0 Spacing (≥ 0.5 mm on ≥ 4 teeth) 2 points/arch = 2 Diastema Mx. central incisor ≥ 2 mm 2 points = 0 Tooth transposition 2 points/tooth = 0 Skeletal asymmetry (non-surg.) 3 points = 0 Additional treatment complexities 2 points for each occurrence 1- _____ 2- _____ 3- _____ 4- _____ 5- _____ Total = 2	
5- Crowding 0 - 1 mm = 0 point 1.1 - 3 mm = 1 point 3.1 - 5 mm = 2 points 5.1 - 7 mm = 4 points > 7 mm = 7 points Total = 2		6- Occlusal relationship (Angle classification) Class I up to end to end = 0 point End to end Class II or III = 2 points per side Full cusp Class II or III = 4 points per side Beyond Class II or III = + 1 addl. point/mm/side Total = 0	
Total DI = 18		Note: Shaded cells must be preserved to evaluators' notes.	

Figure 5 - Calculation of the Discrepancy Index (DI) adapted by BBO.

Maxillary protraction would be performed (a) to correct the anteroposterior discrepancy, and (b) to procline the incisors with finger springs. This procedure would make use of Hickham's chin cup. After this stage, the patient would be monitored every six months until the ideal moment came to implement the second treatment phase.

At this stage, no orthodontic appliance was placed in the patient's lower dental arch.

TREATMENT PROGRESS

The modified Haas appliance was installed and the patient was instructed to make $\frac{1}{4}$ turn activations every 12 hours for 15 days. After this period, the expander was stabilized and the patient started to wear Hickham's chin cup with a force of 400 g on each side for 16 hours/day for 11 months. After this period, the modified Haas appliance was removed and the patient began being evaluated every six months.



Figure 6 - Intermediate facial and intraoral photographs.

RESULTS

After analysis of the examinations carried out in planning the second treatment phase, it was observed that the objectives proposed for the first phase had been fully accomplished (Figs 6 to 10 and Tab 1). From a dental perspective, anterior and posterior

crossbites were corrected, and consequently overbite and overjet were also resolved, thus improving alignment. As planned, a pattern of Class II molar relationship was attained through forward displacement of the maxilla, and sufficient space for proper eruption of teeth #12 and #22.

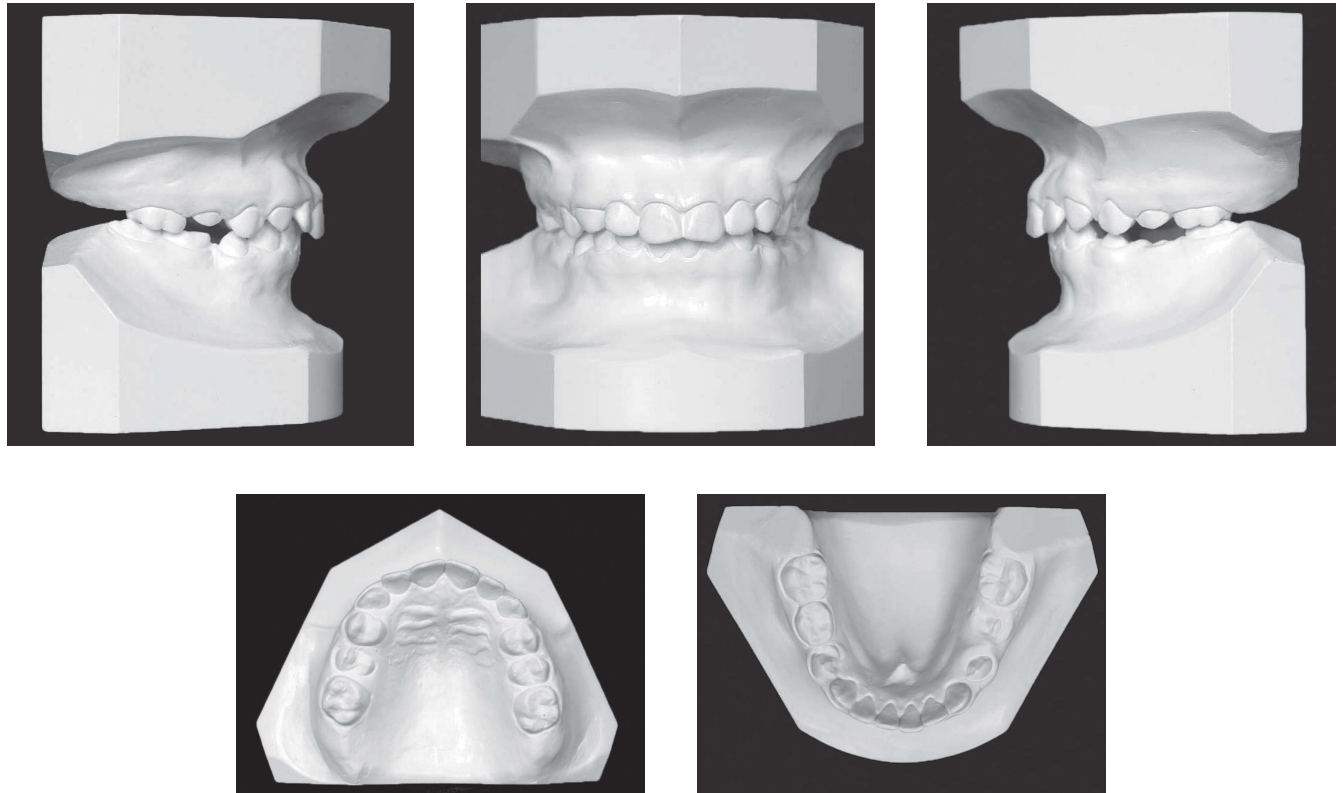


Figure 7 - Intermediate cast models.

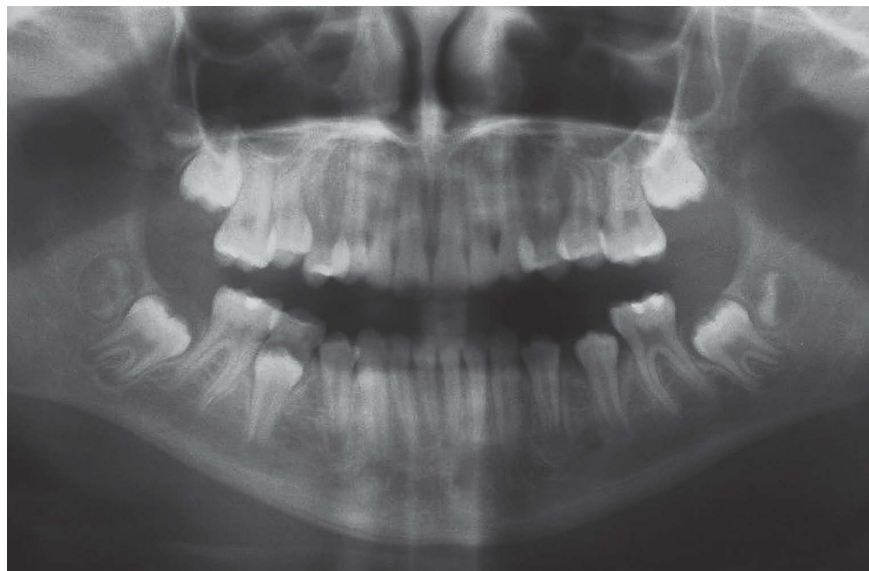


Figure 8 - Intermediate panoramic radiograph.

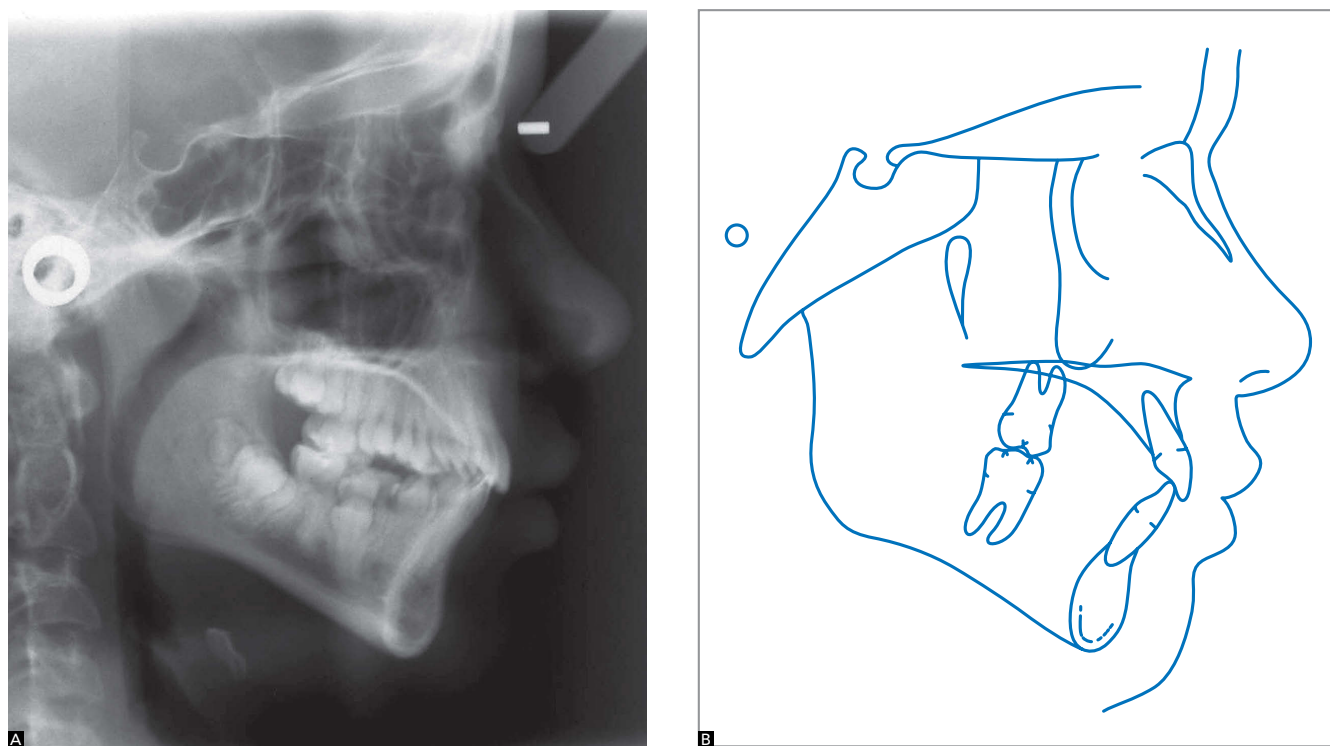


Figure 9 - Intermediate profile cephalometric radiograph (A) and cephalometric tracing (B).

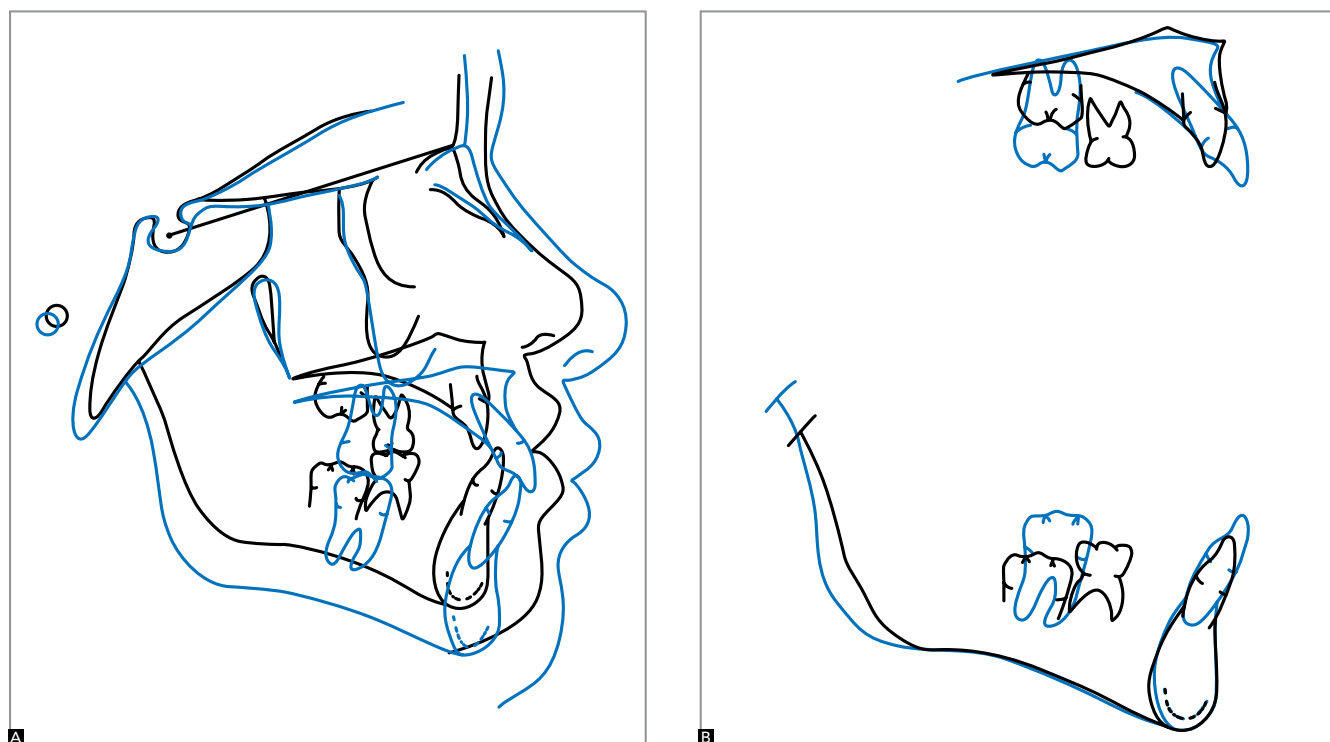


Figure 10 - Total (A) and partial (B) superimposition of initial (black) and intermediate (blue) cephalometric tracings.

Cephalometrically, there was an increase in the ANB angle to 5° (SNA = 82° and SNB = 77°) and a significant improvement in Wits value (Wits = 0 mm). This change was especially due to displacement of the maxilla forward and downward, although there was a slight counterclockwise rotation of the mandible (SN-GoGn increased from 36° to 33° and FMA went from 21° to 17°).

TREATMENT PLAN (PHASE 2)

After four years monitoring patient's development with appointments every six months, the second treatment phase started during the period of pubertal growth spurt, when the patient was 11 years and 10 months old. The goals in this phase were to align and level the teeth, achieving a perfect molar relationship and ultimately finishing the treatment. After finishing, extraction of third molars would be indicated. To this end, a preadjusted fixed orthodontic appliance, Roth prescription, 0.022 x 0.028-in slot would be bonded to upper and lower dental arches. In the finishing stage, individualized bends would be placed as required in stainless steel, 0.018 x 0.025-in archwires, and intermaxillary elastics would be prescribed. After finishing, the retention phase would begin with the use of a wraparound removable appliance placed in the upper arch and a lingual canine-to-canine retainer in the lower arch.

TREATMENT PROGRESS

The upper arch received orthodontic bands with convertible triple tubes (0.051-in) welded to them, placed on teeth #16 and #26. Thereafter, preadjusted metal brackets (Roth prescription, 0.022 x 0.028-in slot) were bonded to upper incisors for alignment and leveling with the aid of Twistflex 0.018-in wire and stainless steel 0.016-in and 0.018-in wire, with expansion loop. After slight flaring of incisors, brackets were bonded to upper canines and premolars.

As of his moment, straight archwires made with 0.016-in, 0.018-in and 0.020-in were used. Eighteen months into treatment, teeth #17 and #27 erupted and were included in alignment and leveling of teeth. Upon finishing, as planned, rectangular 0.018 x 0.025-in stainless steel archwires were formed, torqued and individually coordinated as needed.

Orthodontic bands with convertible rectangular double tubes were fitted to teeth #36 and #46 in the lower arch, and 20 months into treatment, brackets were bonded to teeth #37 and #47. Alignment and leveling was performed using 0.018-in twist-flex archwires and round 0.016-in, 0.018-in and 0.020-in stainless steel archwires. The case was finished with 0.018 x 0.025-in rectangular stainless steel archwires with form, torques and coordination performed as needed on an individual basis. Class II intermaxillary elastics in Class II direction were also employed to decrease lower anchorage and thus achieve a perfect molar relationship. After performing this step, positions of maximum habitual intercuspation (MHI), centric relation and functional guidances (right and left laterality, and protrusion) were verified.

After ensuring that all planned objectives had been achieved, upper and lower fixed orthodontic appliances were removed and the retention phase began. In this phase, a removable wraparound appliance was fitted in the upper dental arch with a buccal 0.032-in stainless steel arch. The patient was instructed to wear it 24/7 for 18 months. After this period, she would wear it 12 hours a day for six months, then only at nighttime for another six months. At the end of this period, the case would be assessed to determine whether or not to suspend its use altogether. In the lower arch, a round 0.018-in stainless steel fixed canine-to-canine retainer was bonded permanently to the lingual surfaces of teeth #33 through #43.

RESULTS

At the end of treatment, additional exams were required (Figs 11 to 14). They revealed that results were very favorable as all objectives were clearly achieved. Concerning the facial features, as shown in Figure 11, the smile exhibits an adequate exposure of upper incisors, and the lower lip is parallel to the upper teeth, displaying an excellent smile arc. Balanced facial symmetry and lip competence can also be observed. In analyzing the profile, it appears that despite an overall harmony, the mandible still shows slight protrusion.

In examining the teeth (Figs 11 and 12), it was observed that proper alignment and leveling were achieved,

as well as proper occlusion with a perfect relationship between upper and lower molars, and between the upper and lower canines, on both sides. Overbite, overjet, posterior crossbite and lower midline were corrected. The spaces in the lower dental arch were closed and proper intercuspation obtained. There was an increase in intercanine and intermolar widths in both dental arches. In the upper arch, the intercanine width was 25 mm to 36 mm, and intermolar width 41 mm to 51 mm. In the lower arch, the intercanine width was 20 mm to 29 mm, and intermolar width 39 mm to 44 mm. Functional harmony was attained in protrusive position, as well as right and left laterality and the centric relation



Figure 11 - Final facial and intraoral photographs.

coincided with the intercuspid position. It is noteworthy that all these results were achieved with only mild apical remodeling. No sign of significant root resorption was observed at the end of treatment (Fig 13).

As expected, several skeletal changes were observed. Mandibular growth occurred in the anterior direction, which caused a decrease in the ANB angle from 3.5° to 1° while the SNA angle remained unchanged and the SNB angle rose from 77.5° to 80° . The vertical dimension was controlled, with a significant decrease in the mandibular plane angle (SN-GoGn changed from 36° to 29° and FMA from 21° to 17°). These data can be viewed in Figure 14 and Table 1.

Cephalometric total superimpositions revealed that the maxilla and mandible moved forward and downward. Partial maxillary superimpositions during the first phase showed vertical development of the alveolar process in the molars, and a substantial change in the inclination of upper incisors. In the second phase, molar mesialization and extrusion were observed along with mild flaring and extrusion of incisors. Partial mandibular superimpositions during the first phase showed mesialization and extrusion of molars, with flaring and extrusion of incisors. In the second phase, molar extrusion and incisor uprighting were noted.

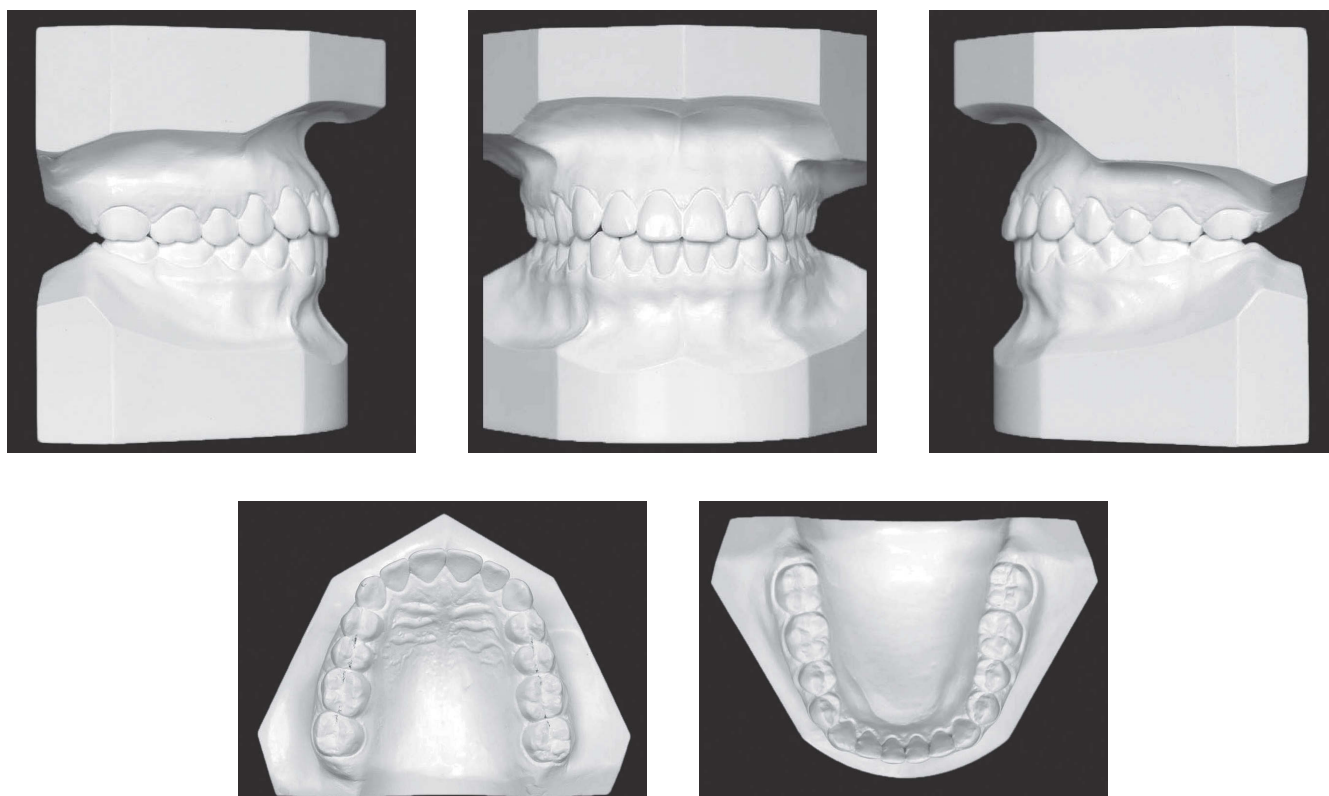


Figure 12 - Final dental casts.

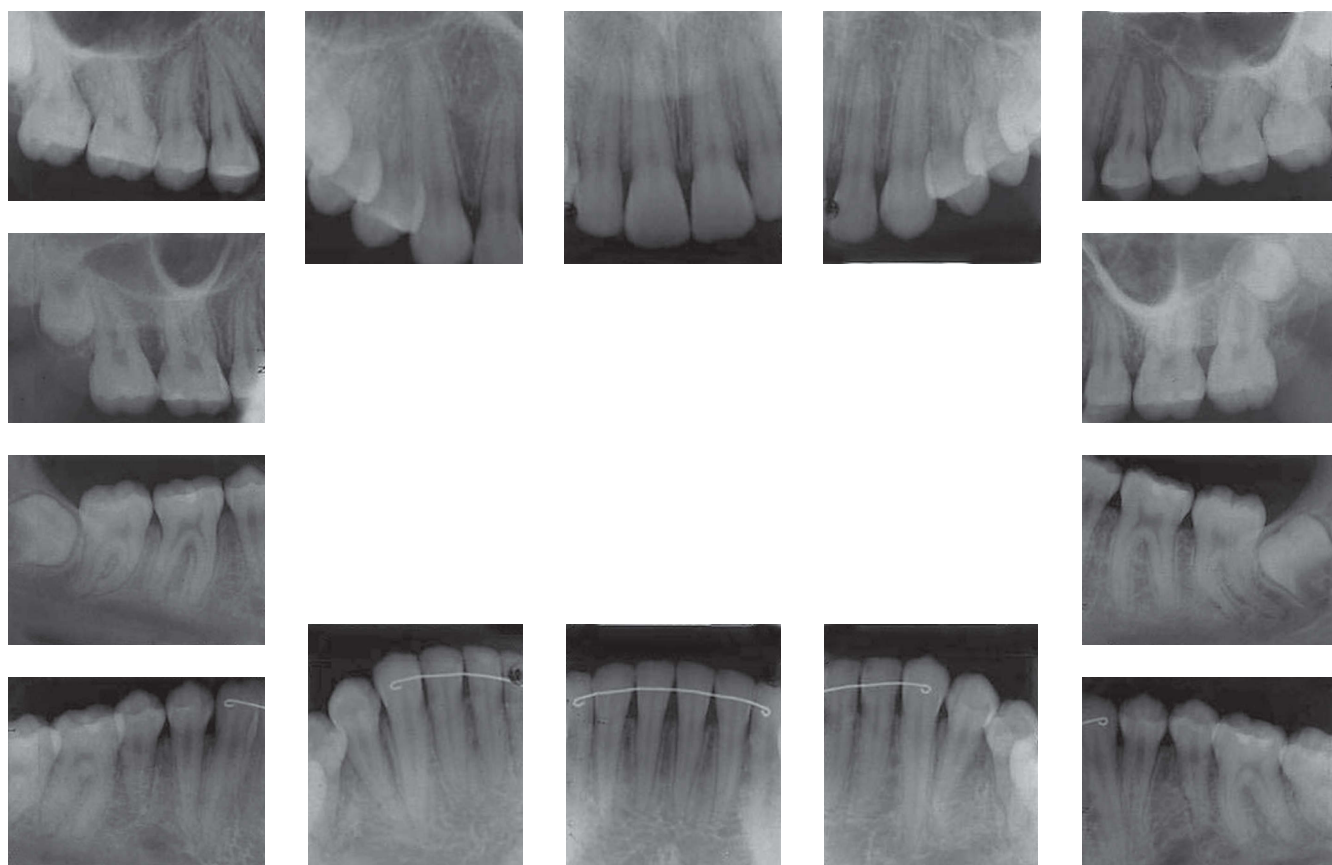


Figure 13 - Final periapical radiographs.

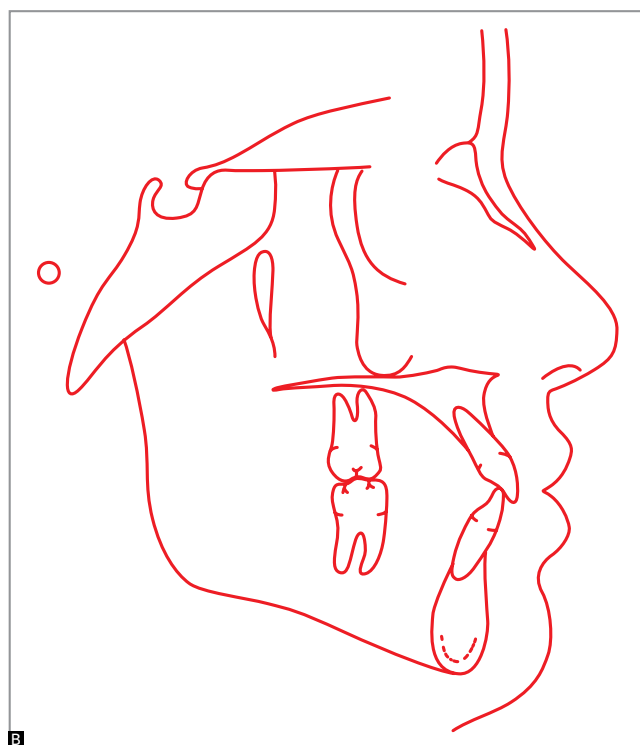


Figure 14 - Final profile cephalometric radiograph (A) and cephalometric tracing (B).

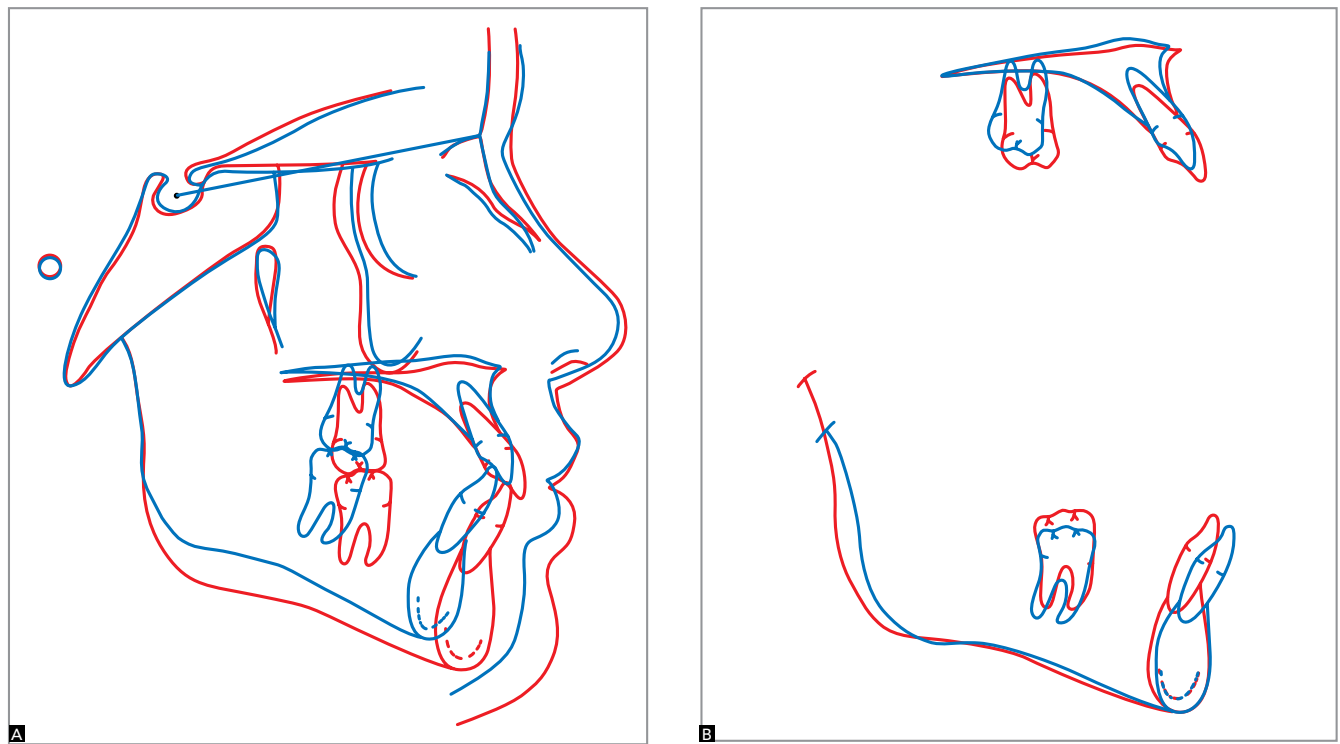


Figure 15 - Total (A) and partial (B) superimpositions of intermediate (blue) and final (red) cephalometric tracings.



Figure 16 - Total (A) and partial (B) superimpositions of initial (black) and final (red) cephalometric tracings.

Table 1 - Initial (A), intermediate (A1) and final (B) cephalometric values.

	Measurements		Normal	A	A1	B	A/B diff.
Skeletal pattern	SNA	(Steiner)	82°	81°	82°	81°	0
	SNB	(Steiner)	80°	77.5°	77°	80°	2.5
	ANB	(Steiner)	2°	3.5°	5°	1°	2.5
	Angle of convexity	(Downs)	0°	8°	13°	1°	7
	Axis Y	(Downs)	59°	52°	55°	54.5°	2.5
	Facial angle	(Downs)	87°	93.5°	92°	95°	1.5
	SN-MP	(Steiner)	32°	36°	33°	29°	7
	FMA	(Tweed)	25°	21°	17°	17°	4
Dental pattern	$\bar{I}$ to MP	(Tweed)	90°	93°	99°	94.5°	1.5
	$\perp$ NA (degrees)	(Steiner)	22°	0°	20°	29°	29
	$\perp$ NA (mm)	(Steiner)	4 mm	0 mm	4 mm	8 mm	8
	$\bar{I}$ NB (degrees)	(Steiner)	25°	26°	30°	25°	1
	$\bar{I}$ -NB (mm)	(Steiner)	4 mm	4 mm	7 mm	5 mm	1
	$\frac{1}{1}$ - Interincisal angle	(Downs)	130°	151°	125°	126°	25
	$\bar{I}$ -APo	(Ricketts)	1 mm	4 mm	4 mm	4 mm	0
Profile	Upper lip — S line	(Steiner)	0 mm	2 mm	2 mm	0 mm	2
	Lower lip — S line	(Steiner)	0 mm	3.5 mm	2.5 mm	1 mm	2.5

FINAL CONSIDERATIONS

Diagnosis and treatment planning of Class III malocclusion should be performed judiciously. Moreover, patients and their families should be made aware of the entire process as results can be unpredictable. Even if goals and a success rate have been established, the prognosis is unclear, since it depends largely on case development and patient compliance. Even so, it is likely that once patient's growth has ended the need for retreatment by dental compensation¹ or surgical intervention may still exist.²

No consensus has yet been reached in the literature regarding the ideal time to start treatment since some authors posit that growth and development of the craniofacial complex is genetically determined, and therefore unalterable. For these authors, correction of most Class III cases necessarily involves surgery. Furthermore, orthodontic treatment should be started immediately after the growth spurt period has ceased. Other authors however — although agreeing with the role of heredity in the etiology of Class III — believe they can change growth pattern and direction by means of a non-surgical approach capable

of minimizing the malocclusion or even treating it successfully.² When the patient is in the phase that precedes the pubertal growth spurt, early treatment is indicated given that Class III malocclusions tend to become increasingly severe over time; the reason being that mandibular growth remains active for a longer period than maxillary growth.^{2,3} Treatment of the case reported here was conducted in two phases. It was initiated when the patient was six years and six months old. Younger individuals tend to achieve more favorable results between four and ten years of age, although patients whose ages range from 10 to 14 years old also present positive results.^{3,4}

In the first phase, rapid maxillary expansion was combined with maxillary protraction using Hickham's⁵ chin cup. This device is easy to fabricate and individualize. It has met with wide acceptance by patients, besides being more stable, especially during sleep.⁶ Although there are several types of appliances for orthopedic protraction of the maxilla, the literature contains no studies comparing their efficiency. The skill of the professional handling the device and patient comfort are important variables when choosing one of these appliances.^{2,7,8}

The second treatment phase began in late mixed dentition. At this stage, there was large overcorrection, and the patient was in Angle Class II malocclusion. Furthermore, the mandible was slightly retruded, which is indicated in this case since she would otherwise continue to present with an unfavorable growth pattern.⁸ At this stage, a conventional fixed orthodontic appliance was used. Treatment outcome was very favorable,

both functionally and esthetically. Upper arch expansion, which had been performed in the first phase, was stable, indicating that the morphological limits were respected. Dental alignment and leveling were achieved in the second stage. Canine and molar occlusion was well established and anterior and posterior crossbites corrected,⁹ with pleasing facial esthetics, good symmetry and adequate exposure of the upper incisors.

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10 commandments of smile esthetics

Andre Wilson Machado¹

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The search for esthetic treatment has persisted in the routine of dental professionals. Following this trend, dental patients have sought treatment with the primary aim of improving smile esthetics. The aim of this article is to present a protocol to assess patient's smile: The 10 Commandments of smile esthetics.

Keywords: Dental esthetics. Orthodontics. Smile.

INTRODUCTION

The search for improved dentofacial esthetics persists in modern society. Thus, inspired by pretty faces and beautiful smiles, patients have sought treatment modalities to improve dentofacial esthetics and yield positive changes in their smile.¹⁻⁶

With a view to achieving ideal esthetic outcomes, some reference parameters must be followed. During many years, these guidelines were based on experts' opinions,^{4,5,7,8,9} in which case special attention should be given to studies conducted by Camara,^{4,5} as they provide essential information on smile esthetics. On the other hand, these clinical guidelines are questionable, since esthetics is a subjective notion and tends to vary among different individuals and

cultures.¹⁰ This fact is a drawback for clinicians who seek a treatment protocol that involves changes in smile esthetics because many articles on this theme were based on author's opinions rather than scientific evidence.

Based on the pioneer research conducted by Kokich et al¹¹, some authors sought digital imaging technology to search for more scientific and consistent references. Since then, several smile variables have been researched as follows: Smile arc;¹² buccal corridor;¹³ amount of gingival exposure at smiling;^{13,14,15} presence of gingival and incisal asymmetry;^{1,11,16,17} presence of anterosuperior diastema;^{3,14} presence of midline shift and changes in axial proclination;^{11,17} maxillary incisors ratio, size and symmetry;^{1,12} among others.

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

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While the wide variety of articles studying those characteristics is of paramount importance to dental literature, it hinders the work of clinicians seeking simple and practical treatment protocols. Professionals usually have a few questions: Where should smile esthetic planning begin? What are the most relevant aspects considered in esthetic treatment? Which scientific references should be considered in a given therapeutic approach?

The aim of this article is to present a protocol to assess patient's smile esthetics: "The 10 commandments of smile esthetics". It particularly aims at simplifying clinical applicability and interdisciplinary planning of smile treatment. With a view to allowing reading to flow as well as for didactic reasons, the issue discussed herein is divided into three main topics: 1) Why should smile be assessed? 2) How should smile be assessed? 3) What should be assessed — 10 commandments.

Two major aspects must be highlighted. First, interdisciplinary treatment, i.e. teamwork, is vital to yield ideal esthetic outcomes. Second, although most 10 commandments are scientific-based, treatment protocol should not be universally applied, but function as a starting point, since the concept of beauty significantly varies. Thus, all commandments presented herein must be subject to discussion among clinicians and patients so as to ensure individualized and satisfactory esthetic planning.

1. WHY SHOULD SMILE BE ASSESSED?

The widely known popular saying "The smile is our business card" must always be respected and considered, since there is scientific evidence evincing the smile as the most important element in the context of dentofacial esthetics.

In the last century, the scientist Alfred Yarbus¹⁷ designed an equipment that registered the movement of human eyes in different situations. His studies revealed that while analyzing facial photographs, people tend to focus attention mostly on the mouth and the eyes.

This hypothesis may be explained not only by the dynamic characteristic of mouth and eyes in comparison to other static structures of the face, but also by the contrast of colors: in the eye, between the iris, the pupil and the sclera; and in the mouth, between the lips, the gingival tissue, the teeth and the dark background. This finding is corroborated by recent publications confirming that during personal interactions greater attention is given to the mouth and the eyes. Additionally, because the mouth is one of the centers of attention of the face, the smile plays

an essential role in facial esthetics.¹⁸ For this reason, we may establish the first aspect of assessing smile esthetics: the smile is a dominant component of facial esthetics.

While conducting researches at the Postgraduate Program in Orthodontics of the Federal University of Bahia (UFBA), we cast doubt on the following: Up to which point is smile really mandatory for us to assess global facial esthetics? Thus, several studies^{13,15,16} submitted manipulated images to orthodontists and laypeople who assessed them in terms of frontal view of the face and closed-up smile. Results revealed no statistically significant differences between the two assessment methods ($P > 0.05$). Furthermore, they demonstrated that assessment of smile esthetics in frontal view (including patient's nose, hair, eyes, facial contour, etc.) or closed-up view (highlighting patient's smile, only) yields the same degree of perception, thereby suggesting no influence of the face over esthetical assessment of different features of the smile. These data reinforce the supremacy of the smile in the context of global facial esthetics.

Once we realize the importance of the smile in a facial context, we are able to extrapolate even further. It is determining not only in the perception of facial attractiveness, but also with the perception of one's psychological characteristics. The presence or absence of deleterious alterations in an individual's smile significantly influences how this individual is perceived and evaluated.¹⁰ Negative alterations may affect one's personality, intelligence, emotional stability, dominance, sexuality and one's behavioral intentions of interacting with other people.¹⁰ These characteristics are easily perceived when dental treatment includes improvements in smile esthetics. You have certainly witnessed improvements in patient's self-esteem and quality of life after esthetic treatment is performed.

Thus, the above explains why patients seek dental treatment with chief esthetic complaint. Whenever patient's smile undergo esthetic changes they become more attractive and young with positive changes in psychological terms.

On the other hand, the issue of whether orthodontic planning has dealt with smile esthetics in order of priority is subject to discussion. The study conducted by Schabel et al,¹⁹ for example, revealed no strong relationship between well-finished orthodontic cases, from an occlusal standpoint, with smile esthetics. In other words, the authors suggest incorporating new criteria that includes smile esthetics in the overall evaluation of orthodontic cases.

2. HOW SHOULD SMILE BE ASSESSED?

Smile evaluation is basically performed by clinical means such as photographs and filming. In fact, clinical examination is prevalent in a dental context; however, registering patient's data is also necessary. To this end, photographs have always been gold standard.

Nevertheless, the validity of photographs has been recently questioned in comparison to filming used for registering one's smile. That occurs because the smile is a dynamic and complex movement comprising interaction of several facial muscles that together produce different positions of dentolabial architecture.

According to Rubin,²¹ there are three smile levels or patterns (Fig 1). The commissure smile,²¹ also known as Mona Lisa smile, is commonly found when people greet each other in social contexts or at unusual locations such as the elevator (Fig 1A). In this smile, the commissures are pulled upward, showing or not the teeth. The second type of smile is known as cuspid²¹ or social smile. It has been globally used in self-portraits divulged in social networks. In this smile pattern, the upper lip is uniformly pulled upward showing anterosuperior teeth (Fig 1B), spontaneously or not. It oftentimes help patients with negative smile alterations (such as gingival smile) to disguise them, thereby limiting a more reliable analysis. The third smile pattern is known as complex smile²¹ characterized by movement of lower lip and wide movement of the upper lip. It is also known as spontaneous smile (usually involuntary) which realistically depicts patients' smile design (Fig 1C). According to Camara,⁵ esthetic planning should be based on complex smile, since social smile may not correspond to reality as it may represent a voluntary movement previously learned.

Thus, the difficulty in accurately registering patient's smile at the exact moment and with static photographs is clear. Furthermore, photographs are also hindered when the patient is encouraged to smile, since what is funny for some people is not funny for others.⁵

Based on the aforementioned difficulties, it seems obvious to understand that registering patient's smile by filming may provide clinicians with more reliable and elucidating data.²⁰ Additionally, the same technique provides another piece of highly relevant information for esthetic treatment planning: Study of different levels of anterior teeth exposure while speaking (Figs 2A to 2D). Importantly, the filming method also has some disadvantages such as: a) The final quality of frames taken from the film is lower than the quality of photographic images; b) filming requires more data storage space (bytes); c) filming requires specific technical knowledge for taking and assessing it.²²

In short, clinical assessment by means of through clinical examination associated with communication between clinicians and patients provides reliable data. Similarly, photographic protocols provide coherent smile data, thereby favoring esthetic treatment planning. Lastly, filming proves to be a complete and interesting tool that provides clinicians with dynamic data on smile and levels of anterior teeth exposure (Fig 2).

3. WHAT SHOULD BE ASSESSED — THE 10 COMMANDMENTS OF SMILE ESTHETICS

As previously mentioned, articles researching isolated features of the smile are of major scientific importance; however, they pose difficulties to clinicians who seek step-by-step instructions to plan maximum smile esthetics. Thus, this article comprises 10 topics (ten commandments) that aid, in a practical and simplified manner, orthodontic and/or esthetic planning. Furthermore, it is useful for communication between clinicians and between patients and clinicians.

The ten commandments suggested herein are as follows: 1st) Smile arc — Maxillary incisors in vertical position; 2nd) Maxillary central incisors ratio and symmetry; 3rd) Anterosuperior teeth ratio; 4th) Presence of anterosuperior space; 5th) Gingival design; 6th) Levels of gingival



Figure 1 - Different types of smile: A) commissure smile; B) social smile; and C) spontaneous smile.

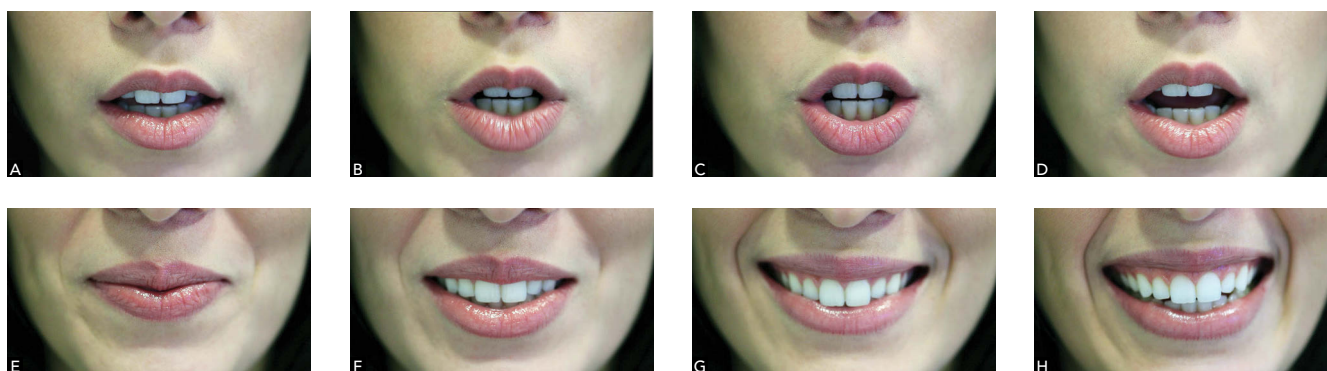


Figure 2 - Frames showing different degrees of incisor exposure. **A–D**) at speaking and **E–H**) at smiling.

exposure; 7th) Buccal corridor; 8th) Midline and tooth angulation; 9th) Details — Tooth color and anatomical shape; 10th) Lip volume.

Special attention is given to disposition of anterosuperior teeth (canine to canine or first premolar to first premolar) or the area known as **esthetic zone** where central incisors are known as key elements and characterize the term "**dominance of central incisors**" (Fig 3). In short, central incisors must be highlighted as true protagonists of smile. Thus, commandments from 1 to 4 are directly related to "dominance of central incisors".

1st commandment — Smile arc : Maxillary incisors in vertical position

Esthetic planning must begin in the noblest area of the smile: Maxillary central incisors.^{7,8,9} The 1st commandment states the ideal vertical positioning for maxillary incisors at smiling. That is the first step to be planned in esthetic treatment.

Figure 4A shows a smile with satisfactory tooth color and anatomical shape. Despite such qualities, the smile shown in Figure 4A is considered highly unesthetic, particularly due to inappropriate vertical incisors positioning considered as essential for smile esthetics.^{2,8,9}

An ideal smile arc has the maxillary incisal edges slightly contouring the lower lip (Fig 5A). The ideal configuration of smile arc is described as follows: convex arc, curved arc, consonant arc, deep plate-shaped arc, etc.^{4,5,7,8,9,23}

On the other hand, when the incisal contour of teeth in the esthetic zone does not follow the contour of the lower lip, the smile arc is classified differently.²³ First, it is described as plane or straight in which the incisal edges of teeth in the esthetic zone are nearly at the same level of the edges of posterior teeth, parallel to the ground and nor following the contour of the lower lip (Fig 5B). Additionally, it is

also described as inverted, reverse or nonconsonant arc in which the incisal edges of teeth do not contour the lower lip and have an inverted curvature²³ (Fig 5C).

A comparison between convex and inverted smile arcs raises the following question: Why are they complete opposites from an esthetic standpoint? First, in terms of beauty of the arched contour of incisal edges of teeth in the esthetic zone, considered as the most important factor of dental esthetics (Fig 6).⁹ Second, in terms of joviality. The more arched the incisal contour of anterosuperior teeth is, the younger the smile looks; whereas the more plane, the older it looks. Additionally, according to the literature,²⁴ the older someone is, the less maxillary incisor exposure and the more mandibular incisor exposure there will be both at smiling, at rest or while speaking.²⁴ These changes are physiological and are caused by several factors as follows: increased perioral muscle flaccidity, genetics, ethnic group, age and sunlight exposure, all of which result in less maxillary teeth exposure.⁶

In modern society, esthetics and joviality are strongly associated, i.e., the beautiful and the young are interconnected. A few esthetic features have been highlighted in TV stars, singers and models. Greater maxillary incisor exposure at rest is one of them and has been associated with beauty, joviality, sensuality and sexuality. It is possible to infer that the current standard of beauty comprises not only a beautiful smile, but also voluminous lips and greater maxillary incisor exposure at smiling, at rest or while speaking.

This finding may guide the following dental planning modalities: Esthetic restoration and/or rehabilitation, manufacture of complete denture and vertical movement of incisors during orthodontic treatment. In orthodontic treatment, the clinician may adapt the protocol of bracket bonding and/or add bends to orthodontic archwires with a view to increasing incisors extrusion and, therefore,

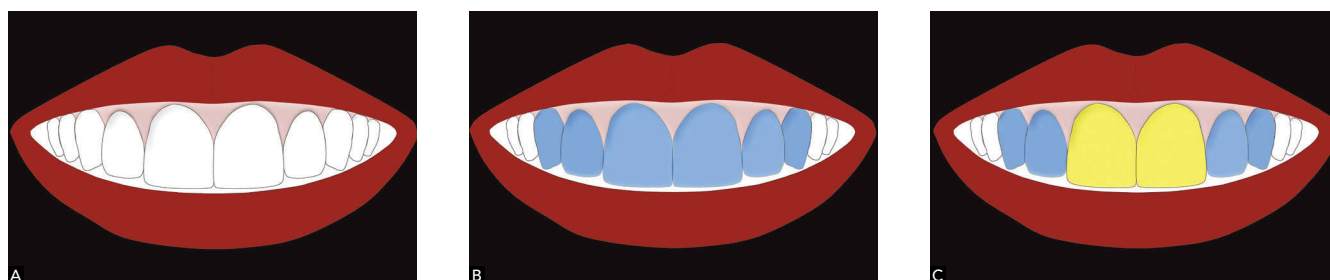


Figure 3 - Smile illustration: A) ideal design; B) smile esthetic zone - in blue and C) dominance of central incisors - in yellow.



Figure 4 - Case report showing the esthetic impact of changes in vertical positioning of incisors at smiling: A) initial smile showing inverted smile arc; B) illustration showing final incisors positioning; C) alignment and leveling outcomes with changes in bonding protocol following lower lip contour; and D) final result.

rendering them more visible at rest and at smiling by means of achieving proper smile arc (Fig 7).

We conducted another research to test the vertical position of maxillary central incisors and found that slightly extruded central incisors were more attracted than slightly intruded ones. Results reveal that the vertical position of incisors is when the edge of central incisors is near the lower lip and far from the incisal edge of lateral incisors and canines, thereby ensuring dominance of central incisors.² In other words, the incisal edge of maxillary central incisors must be below the cuspid tip of canines (Fig 5A).

With a view to aiding clinicians to achieve ideal design of incisal contour in the esthetic zone, the step between

central and lateral incisors must range from 1.0 - 1.5 mm for women and 0.5 - 1.0 mm for men (Fig 6).² This finding reveals that convex smile arcs are more suitable for women (Fig 5A) whereas convex or plane arcs are acceptable for men (Fig 5B).

After discussing this concept, we are able to reassess Figure 4A, in which case the need for maxillary central incisor extrusion to fulfill the 1st commandment is clear (Fig 4B). Importantly, the need for individualizing orthodontic bracket bonding should be highlighted. Should height guidance provided by the brackets manufacturer had been used in this clinical case, suggesting that canines should be as high as central incisors,



Figure 5 - Different types of smile arc: A) convex or curved; B) plane or straight; and C) inverted or reverse.

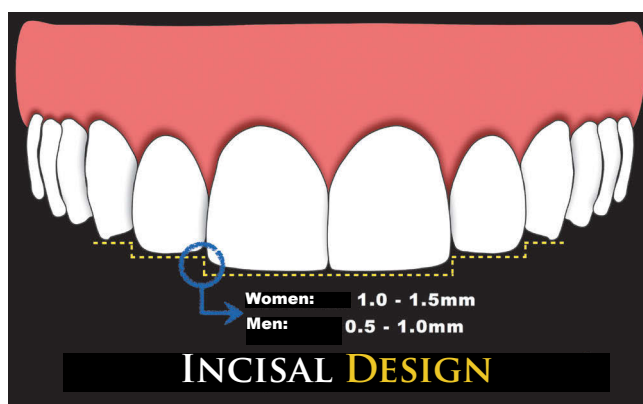


Figure 6 - Ideal incisal contour design of teeth in the esthetic zone.

treatment would hardly achieve the ideal smile arc. It would achieve a plane arc instead. Similarly, should bonding be based on brackets positioned on the center of clinical crowns, the ideal curved smile arc would not be achieved. Thus, orthodontic bonding should be individualized in the esthetic zone, following patient's lower lip contour and anatomical shape of teeth. Figure 4C shows bracket positioning following this principle and with the major aim of extruding central incisors. In this case, the height of brackets bonded to canines was 3.5 mm, whereas the height of brackets bonded to central incisors was 5.5 mm. Thus, after alignment and leveling, maxillary central incisors were

ideally positioned in accordance with the aforementioned recommendations, thereby achieving a pleasant and young smile (Fig 4D).

Importantly, planning vertical changes of teeth in the esthetic zone requires that three important points be considered: The first regards occlusal maxillary plane and head inclination while assessing patient's smile. Clockwise maxillary plane and head inclination lead to greater incisor exposure. As a result, convex smile arcs are more easily found. On the other hand, counterclockwise maxillary occlusal plane inclination and patient's head inclination backwards hinder convex smile arcs to be seen and/or achieved.

The second point is with regards to mandibular function which must be absolute in dental planning. In other words, esthetic goals must not disrupt occlusal balance. Incisor extrusion or intrusion may influence protrusion and laterality. Therefore, mandibular function must be carefully assessed in which case occlusal adjustments might render necessary.²

The third point to be considered is axial proclination of maxillary and mandibular incisors (interincisal angle). This feature is a determining factor that allows or not incisors extrusion, thereby increasing smile visibility at rest and while speaking. In the event of proclined incisors (decreased interincisal angle), extrusion is hindered or hampered as in cases of Class I bimaxillary protrusion or Class I division I malocclusion. In these cases, incisors angulation must be corrected so as to optimize vertical positioning.

To bring this commandment to a conclusion, we carefully reassess Figure 6 which shows that, with a



Figure 7 - Strategies used to extrude maxillary incisors so as to achieve ideal incisal contour design and increase exposure at rest, smile and while speaking: **A)** changes in height of bracket positioning; and **B)** orthodontic arch bends.

view to ideally adjusting the incisal contour of teeth in the esthetic zone, gingival margin positioning also changes. In most clinical cases, clinicians face the following: If central incisors incisal edge is below canines incisal edge, what is the final design of gingival margins? Such questioning is answered by the 5th commandment.

Summary of the 1st commandment

- » Vertical positioning of maxillary incisors is determining to achieve an attractive, young smile.
- » The incisal edge of maxillary central incisors must be below the cuspid tip of canines, ensuring dominance of central incisors.
- » The step between central and lateral incisors must range from 1.0 to 1.5 mm for women and from 0.5 to 1.0 mm for men.

2nd commandment – Ratio and symmetry of maxillary central incisors

Once maxillary incisors vertical positioning is determined, maxillary central incisors ratio and symmetry are adjusted. Thus, the 2nd commandment asserts that ideal width-height (W/H) ratio and symmetry of central incisors must be achieved.

The clinician must register the width and height of maxillary central incisors clinical crowns so as to determine W/H ratio (Fig 8). Subsequently, he must plan 75 to 85% ratios which are considered more esthetic (Fig 9A).²⁵ Should values tend towards 75%, central incisors will have a longer pattern widely accepted by women, whereas in 85% ratios, incisors will have a wider pattern widely accepted by men.

In the event of altered W/H ratios, the first step consists in determining whether one of the central incisors has proper W/H ratio. Should that be the case, this tooth will be used as reference (template) to change the other central incisor. Should both central incisors be altered, their height is used as reference for correction. In other words, esthetic central incisors usually have 9.5 to 11-mm high crowns.^{8,9}

Figure 10 shows a patient whose chief complaint was having a big tooth in the esthetic zone. His right central incisor was 9.1-mm wide and 9.5-mm high, thereby producing a W/H ratio of 95%, highly unesthetic. His left central incisor, however, was 8.0-mm wide and 9.5-mm high, thereby producing a W/H ratio of 84% which is within normality. Thus, treatment comprised 0.5-mm interproximal wear on the mesial and distal surfaces of right central incisor, followed by orthodontic space closure. As a result, ideal W/H ratio remained on the left side, whereas it changed on the right side.

Subsequently, with a view to fulfilling the 2nd commandment, left central incisor reconstruction was repeated so as to achieve maximum symmetry between central incisors.

The demand for symmetry between central incisors is based on the clinical assumption that the nearer the midline, the greater the need for symmetry, and the further from the midline, the higher the number of slight asymmetries clinically acceptable.⁹ With a view to testing this hypothesis, we conducted a research assessing the esthetic impact of central and lateral incisor asymmetries on the smile of two adult female patients (Caucasian and melanoderma).¹ Our results corroborate the aforementioned hypothesis, since a slight 0.5-mm maxillary central incisor asymmetry was identified as unesthetic by orthodontists and laypeople. On the other hand, slight asymmetries on the side of incisors may go unnoticed,¹ while in canines, even greater asymmetries may not be identified (Fig 11).¹⁶

Hence, in cases requiring orthodontic finishing, we suggest that multidisciplinary treatment be conducted to achieve maximum symmetry between maxillary central incisors. Figure 12, for instance, shows left central incisor W/H ratio of 78% used as template for treatment. After orthodontic treatment, the patient was referred to cosmetic restoration of right central incisor and reshaping so as to fulfill the 2nd commandment, thereby achieving proper W/H ratio and maximum symmetry between maxillary central incisors.

Summary of the 2nd commandment

- » Take note of width/height ratios for maxillary central incisors.
- » Aim at esthetic proportion (75 – 85%) and maximal symmetry.
- » Symmetry between incisal edges is the most important aspect.

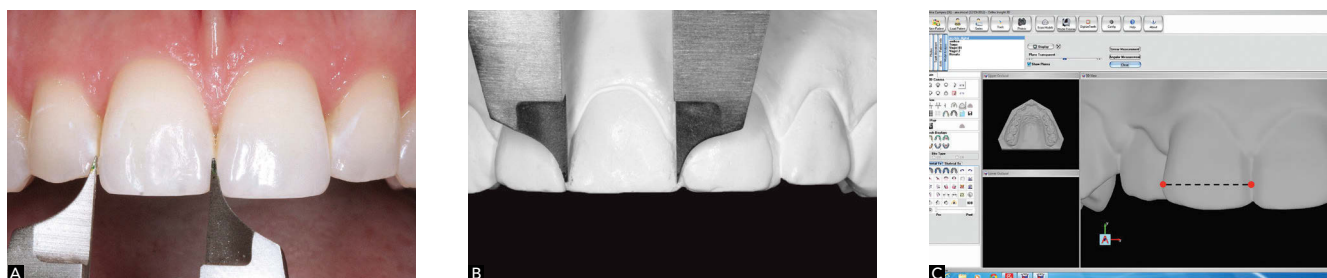


Figure 8 - Different methods employed to measure maxillary central incisors width and height: **A)** clinical caliper measurement; **B)** caliper measurement in conventional model; and **C)** software measurement in digital model.

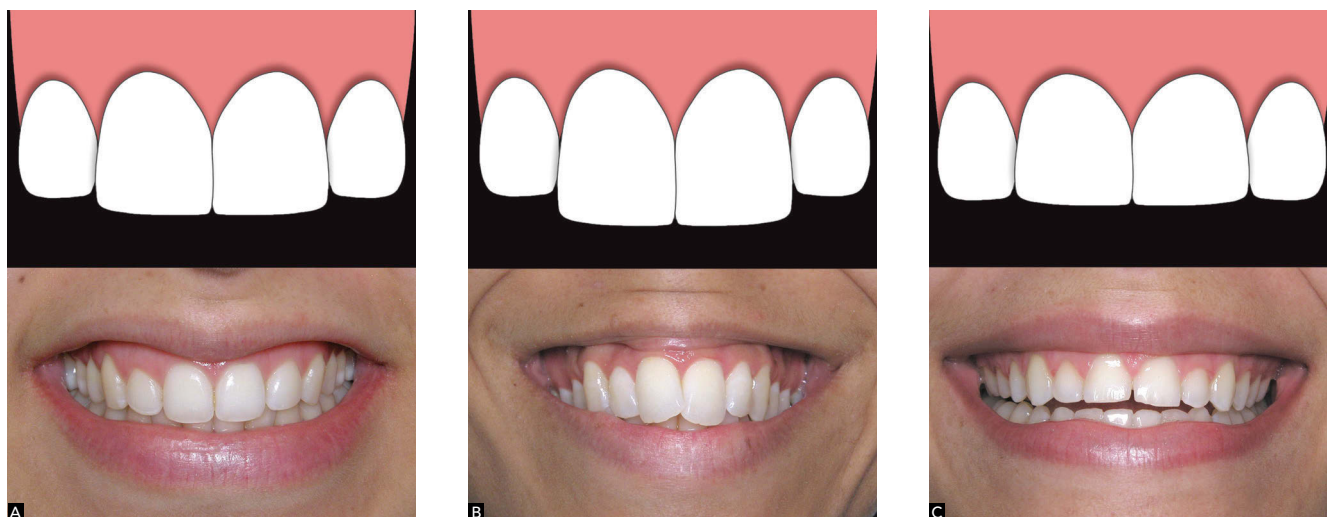


Figure 9 - Different width-height ratio of central incisors: **A)** ideal ratio, between 75 and 85%; **B)** long teeth with ratio < 75%; and **C)** short or squared teeth with ratio > 85%.



Figure 10 - Clinical case illustrating the importance of W/H ratio in smile esthetics: **A)** initial closed-up view of maxillary incisors; **B)** after orthodontic appliance removal; **C)** final result; **D)** final smile.

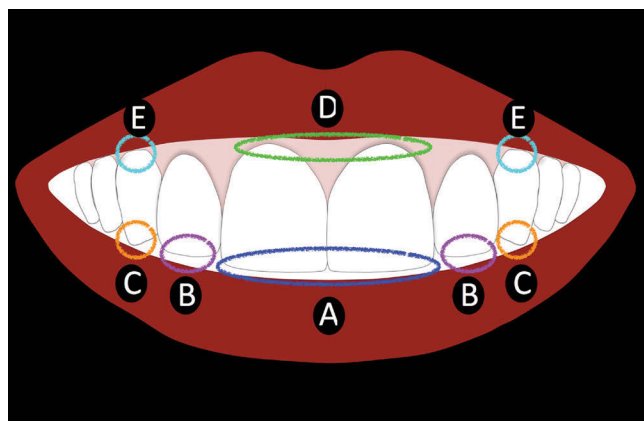


Figure 11 - Limits of esthetic acceptability of incisal and gingival asymmetry in the esthetic zone: **A)** 0.5 mm¹; **B)** 1.0 mm¹; **C)** 2.0 mm¹⁷; **D)** from 1.5 to 2.0 mm^{11,14}; and **E)** from 1.5 to 2.0 mm¹⁶.

3rd commandment — Proportion between anterosuperior teeth

Once the ideal vertical positioning of maxillary incisors is achieved and W/H ratio as well as maximum symmetry between central incisors is attained, the proportion between anterosuperior teeth is then adjusted. This feature is widely considered in

Dentistry and it is based on the golden ratio initially proposed by Levin in 1978.²⁶ According to the author, in frontal view, there exists a width proportion of teeth seen in perspective. This fact is shown by Figure 13 in which visible lateral incisor width accounts for 62% of central incisor width, while canine width accounts for 62% of lateral incisor width.

A recently published research²⁷ compared several different proportions, such as 57% (featuring narrower lateral incisors), 67%, 70% and 72% (featuring wider lateral incisors).²⁷ Results revealed that the golden ratio should be applied with caution, as the value of 62% must be interpreted as a mean rather than a standard to be pursued. Furthermore, greater proportions (67% and 70%) have been highlighted as being more esthetic, thereby revealing that there seems to exist a strong preference for wider instead of narrower incisors.

Clinically, this feature is easily noticeable in view of conoid or extremely narrow lateral incisors. There are reference rulers and guides used in the clinical practice. Additionally, digital symmetry guides or

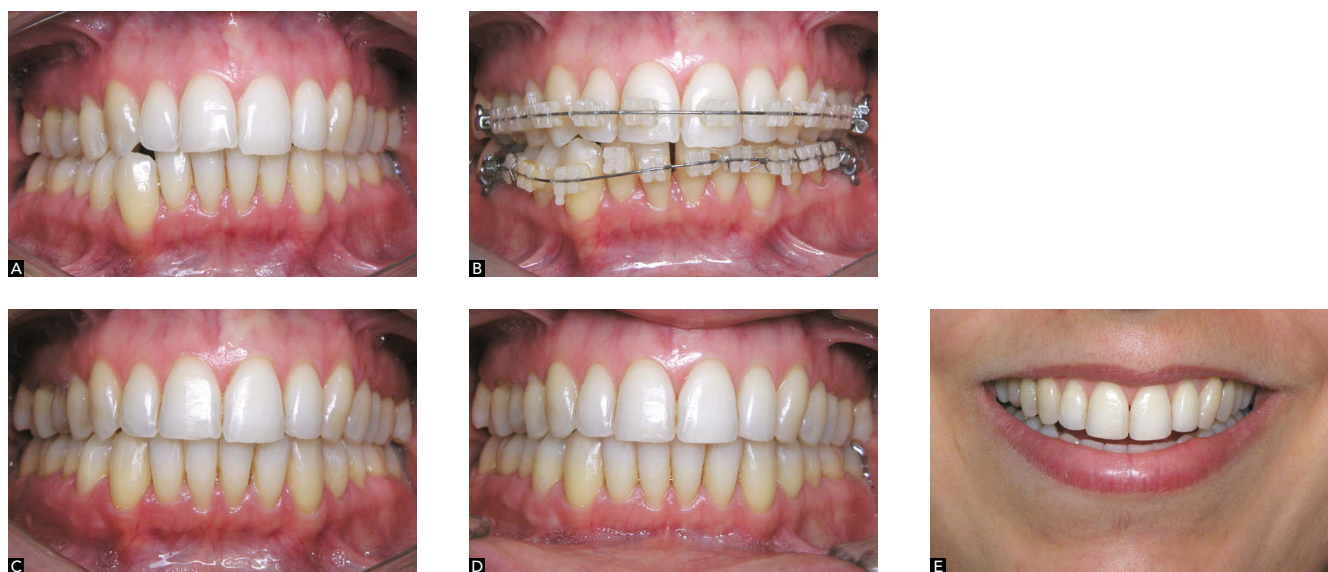


Figure 12 - Clinical case illustrating the importance of symmetry between central incisors in smile esthetics: **A)** initial; **B)** during orthodontic treatment; **C)** after orthodontic appliance removal; **D)** final result; and **E)** final smile.

grids are very useful tools that respect standard proportions and allow us to study and visualize this variable on computer and/or tablet screens. Figure 14, for instance, shows two grids, one used with golden ratio (62% – Fig 14A) and another one used with modified proportion (70% – Fig 14B). They demonstrate that in both smiles, lateral incisors are narrow and do not respect the most esthetically pleasant proportion between anterosuperior teeth.

The case described in Figure 15 shows asymmetrical proportion between anterosuperior teeth. The golden ratio grid makes it easier to clearly identify the discrepancy, revealing that the right lateral incisor had reduced mesiodistal dimension. Orthodontic treatment opened up a space in the lateral incisor area which would undergo further esthetic restoration so as to fulfill the 3rd commandment which is the proportion between anterosuperior teeth. Furthermore, reshaping was performed to improve symmetry between central incisors and adjust the step between central and lateral incisors, emphasizing the dominance of central incisors in one's smile.

Summary of the 3rd commandment

- » Too narrow lateral incisors are unesthetic.
- » Multidisciplinary treatment is necessary.

4th commandment – Presence of anterosuperior spaces

Esthetic perception of diastema in the esthetic zone is widely discussed in the literature. At the same time, it arouses considerable controversy. Nevertheless, one should question the following: Are diastemas in the esthetic zone esthetic or unesthetic? According to the literature,¹⁴ small midline diastemas (not greater than 2.0 mm) might go unnoticed by laypeople. This finding may somehow explain why some famous artists have diastemas and find such spaces attractive. On the other hand, this finding¹⁴ might also be questioned, since it is too optimistic in terms of the impact midline diastemas have over smile esthetics. Do 1.0–2.0 mm diastemas really go unnoticed by laypeople?

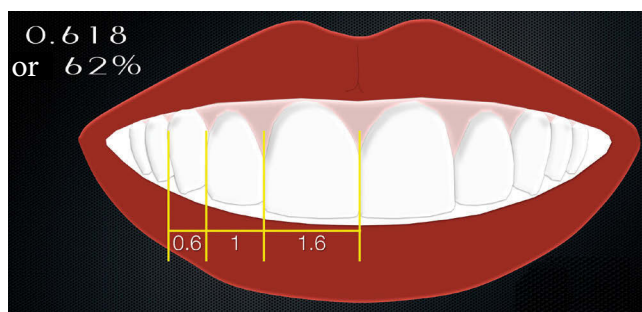


Figure 13 - Smile with golden ratio (62%) between teeth in the esthetic zone.

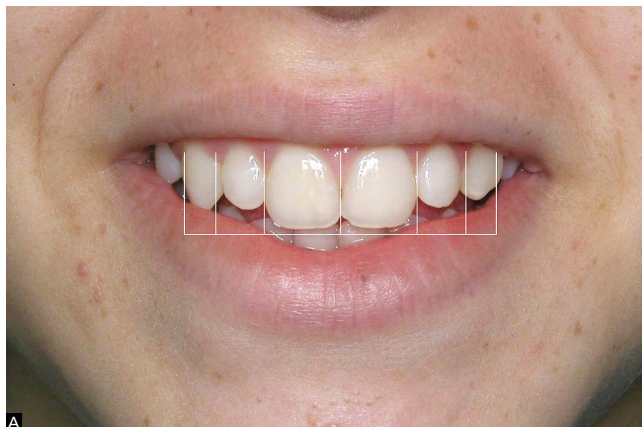
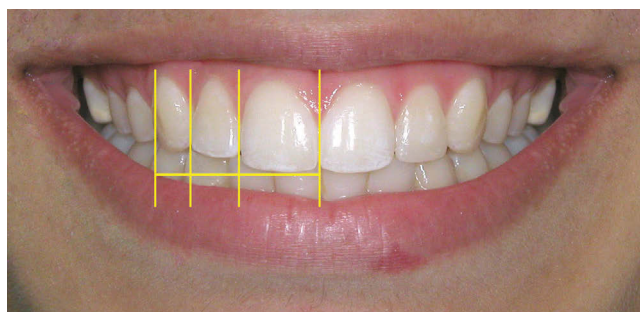


Figure 14 - Digital ratio grid used with two narrow smiles: A) golden ratio grid (62%) and B) grid with modified ratio (70%).



Figure 15 - Clinical case illustrating the importance of proportion between anterosuperior teeth: A) initial closed-up view in the esthetic zone showing right lateral incisor of reduced width (blue arrow); B) initial smile; C) final result showing adequate proportion between teeth in the esthetic zone; D) final smile.

Although esthetics is highly subjective, the 4th commandment asserts that all midline diastemas must be closed either by orthodontic or multidisciplinary treatment. One should also ask whether diastema in the lateral incisors area (mesial, distal or both) affects smile esthetics. With a view to answering this question, we conducted another research to assess the esthetic impact

of diastemas over two female patients' smile.³ Results revealed that the greater the diastema and the nearer the midline, the more unesthetic the smile is. The only exception was for 0.5-mm diastemas in the distal surface of lateral incisors, which were not identified by laypeople. Thus, if space is to remain after orthodontic treatment, the distal surface of lateral incisors should be



Figure 16 - The impact of midline diastema correction over patient's smile: **A)** initial smile; **B)** final smile; **C)** initial frontal view; **D)** frontal view after activator use; **E)** final frontal view after fixed corrective orthodontic treatment.



Figure 17 - Diastema correction in maxillary lateral incisors area: **A)** initial frontal view; **B)** initial lateral view of maxillary left incisor; **C)** final frontal view; and **D)** final view in maxillary lateral incisors area.

the area of choice.³ Figures 16 and 17 show two cases of diastemas in the esthetic zone. In the former, the remaining space was between central incisors; whereas in the latter, the remaining space was in the distal surface of the left lateral incisor. In both cases, with a view to fulfilling the 4th commandment, all remaining spaces were closed.

Summary of the 4th commandment

- » Diastemas in the esthetic zone are unesthetic.
- » All diastemas should be closed.

5th commandment — Gingival design

Gingival tissue architecture must also be taken into account in esthetic treatment. The terms "pink esthetics" and "red esthetics" have been used to describe ideal gingival contour at smiling. Some dental textbooks bring the following parameter of ideal esthetic gingiva: "Canine gingival margin must coincide with central incisors gingival margin, whereas lateral incisors gingival margin must be slightly below this line" (Fig 18A). Indeed, such parameter provides maximum smile esthetics. However, should clinicians follow the aforementioned parameter in cases in which canines and central incisors are equal

in length,² they might position central incisors incisal edge at the same level or above canines. As a result, plane or inverted smile arcs might be produced, and so are unesthetic smiles.

This clinical doubt arouses from the following: Which esthetic parameter is more important? Incisal contour (white esthetics) or gingival design (pink esthetics)? We have recently published a research in which we establish a relationship between esthetic perception and incisal edge smile line as well as gingival margin smile line.² Results reveal that incisal smile design (white esthetics) is the most important factor of dental esthetics.⁹ Thus, in addition to what is recommended in the 1st commandment (smile arc), one may opt for a modified gingival design in which the gingival margin of central and lateral incisors coincide and are slightly (0.5–1.0 mm) below canines, the gingival margin of central incisors is below canines (0.5–1.0 mm) and the gingival margin of lateral incisors is below central incisors (0.5 mm) (Fig 18B). It is clear that extrusion of central incisors must be conducted according to patient's lower lip contour and sex, respecting the recommendation of greater extrusion of incisors for female smiles. Furthermore, the degree of extrusion must not violate lateral guidance.²

Another esthetic parameter widely divulged is the positioning of gingival apices defined as the most apical points of gingival contour. Frontal analysis of teeth in the esthetic zone reveals that gingival apices are located in the center of the crowns or slightly distally. On the other hand, based on the limits of acceptability of smile asymmetry (Fig 11), changes in gingival apices hardly affect one's smile negatively.

Importantly, even after determining the ideal design of gingival margins in the esthetic zone, the clinician might face gingival asymmetry between teeth. Asymmetry between incisal edges of central incisors are considered unesthetic.¹ But how about gingival asymmetry? Can it be identified by laypeople? According to the literature, gingival asymmetry not greater than 1.5–2.0 mm between central incisors^{11,14} go unnoticed by laypeople. We conducted another research at the Federal University of Bahia (UFBA) to investigate the esthetic impact of gingival asymmetry between canines¹⁶ and found the same limit of perception (1.5–2.0 mm) for laypeople. These findings highlight once again that white esthetics is more important than pink esthetics (Fig 11).

Even though a number of studies yields positive results regarding the esthetic impact of asymmetry,^{11,14} the 5th commandment asserts that after determining ideal

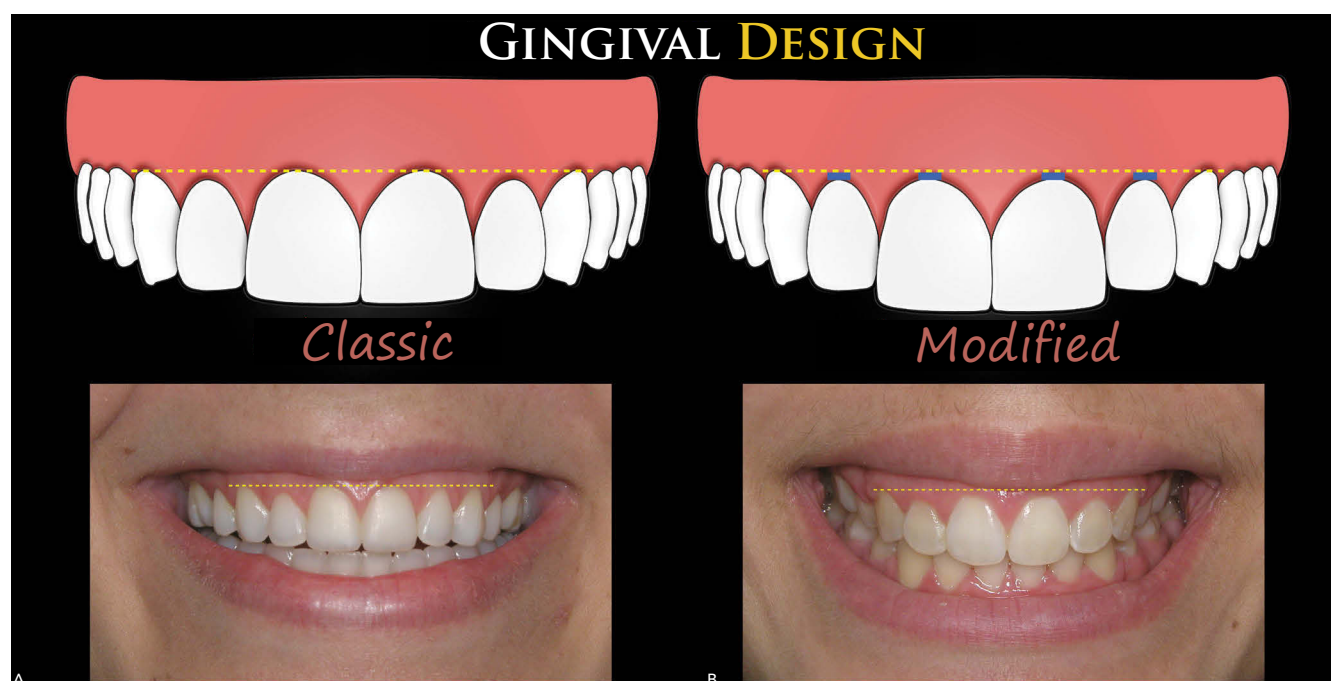


Figure 18 - Two different gingival margin designs: **A)** Classic: leveled canine and central incisor margins, with lateral incisor margin slightly below; **B)** Modified: central incisor margin below canines and lateral incisor margins leveled with central incisors or slightly below them.



Figure 19 - Two clinical cases with gingival asymmetry in the esthetic zone requiring different treatment procedures: **A)** real need for intervention due to great gingival asymmetry exposure at smiling; and **B)** smile without gingival asymmetry exposure and with no need for treatment.

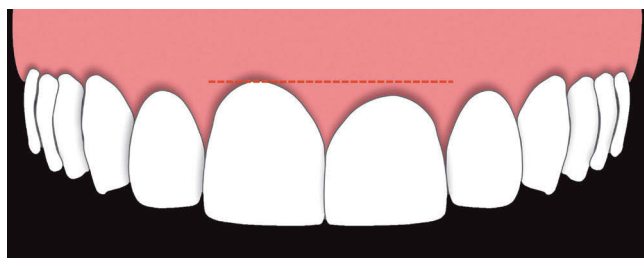


Figure 20 - Gingival asymmetry between maxillary central incisors.

gingival design, whether classic or modified, the clinician should focus on correcting potential asymmetries, provided that they are evident at smiling. Gingival smile displays greater asymmetry and, for this reason, must be corrected. Nevertheless, little gingival display at smiling does not require correction (Fig 19). It is worth noting that should discrepancies be visible at smiling and near the midline, the need for correction is even greater.

Cases of gingival discrepancy between central incisors (Fig 20) are basically corrected by either one of the following three treatment methods: a) gingivoplasty of the lowest incisor; b) intrusion and incisal restoration of one central incisor; c) extrusion of one central incisor with posterior incisal wear.²⁸ The first step to choose the ideal treatment option is to apply the 2nd commandment (maxillary central incisors proportion and symmetry) and determine which central incisor is gold standard. In this case, it is tooth #11, which requires gingivoplasty (a) or intrusion (b). Subsequently, treatment planning requires that the cemento-enamel junction be identified by means of clinical probing and periapical radiograph or tomography so as to determine whether gingivoplasty is feasible or not.

Figure 21 shows a patient with improved smile esthetics after removal of fixed orthodontic appliances; however, with discrepancy between gingival margins and incisal edges of central incisors. Treatment comprised gingivoplasty of right central incisor and esthetic reconstruction of left central incisor, thereby fulfilling all aforementioned commandments.

Summary of the 5th commandment

- » Gingival margin of central incisors must be leveled or slightly bellow (0.5 to 1.0 mm) canines.
- » Gingival margin of lateral incisors must be leveled or slightly bellow (0.5 mm) central incisors.
- » Multidisciplinary treatment is necessary for ideal gingival design adjustment.

6th commandment – Gingival exposure

Assessing the amount of teeth and gingival tissue exposure in the esthetic zone is of paramount importance for smile esthetics. According to Tjan et al,²³ gingival exposure is determined by the smile line classified as high, medium or low (Fig 22).

Importantly, the ideal smile does not require gingival tissue exposure to be eliminated. In fact, many TV stars, models and role models of beauty display the entire length of teeth and little gingival tissue at smiling. As previously mentioned, greater exposure of incisors and little gingival exposure at smiling are esthetic and characteristic of joviality. The major point of clinical scientific discussion is as follows: Is gingival tissue



Figure 21 - Clinical case illustrating incisal and gingival asymmetry correction: **A)** initial smile; **B)** orthodontic treatment result; and **C)** final smile.

exposure at smiling esthetic? If so, what is the ideal amount of gingival exposure? To what extent is gingival exposure acceptable?

According to the literature, gingival tissue exposure at smiling is not a negative feature.^{11,14,15} In a previous study,¹⁵ we found that the maximum limit of gingival tissue exposure is of 3.0 mm, thereby corroborating other studies.^{11,14} Thus, gingival exposure not greater than 3.0 mm is perfectly acceptable, whereas values greater than 3.0 mm are considered unesthetic. Based on these findings and considering the different types of smile (high, medium and low, as shown in Fig 22), the 6th commandment suggests that high smile with gingival exposure not greater than 3.0 mm is more esthetic, followed by medium and low smiles.

Since the theme of gingival smile has already been widely reviewed, it will not be brought to discussion in this manuscript. For this reason, we recommend further reading on the topic.²⁹

The two major aspects to be discussed on the theme of gingival exposure are: a) The need for a treatment planning that contemplates the primary etiology of the case and, therefore, avoids potential risk of failure; b) Avoiding intrusion of maxillary incisors by complying with the aforementioned points. A very common clinical mistake consists in intruding maxillary incisors so as to minimize gingival exposure in cases of normal smile arc. In these cases, loss of ideal incisal smile contour (1st commandment) might be more deleterious than gingival tissue exposure.

Figure 23 shows a smile with great gingival tissue exposure. Orthodontic treatment was performed with extraction of first premolars and, after removing the fixed appliances, the patient was referred to gingivoplasty and manufacture of dental veneers in the

esthetic zone. Subsequently, with the aid of dermatological procedures⁵ that included the use of botulinum toxin, gingival tissue exposure was minimized, thereby favoring satisfactory esthetic outcomes. Importantly, despite being a case of gingival smile, the 1st commandment was fulfilled with an ideal smile arc as well as proper design of incisal edges and modified gingival design.

Summary of the 6th commandment

- » Gingival exposure not greater than 3 mm is not unesthetic.
- » Intrusion of maxillary incisors, especially central incisors, should be avoided.
- » Gingival smile treatment should be guided by its etiology.

7th commandment — Buccal corridor

Buccal corridor is the bilateral space between the vestibular surface of visible maxillary posterior teeth and lip commissure at smiling (Fig 24A).^{8,9} Basically, there are three types of buccal corridors: a) wide, usually followed by narrow maxillary dental arch (Fig 24B); b) intermediate, followed by dental arches of intermediate transverse dimensions (Fig 24C); and c) narrow or nonexistent, associated with severe transverse dental arches (Fig 24D). Literature does not present a consensus regarding the esthetic impact of buccal corridor over smiling. While some studies demonstrate that different buccal corridors do not affect smile esthetics, other state the opposite. We conducted another research at the Federal University of Bahia¹³ and found intermediate buccal corridors to be more esthetic in comparison to wide and narrow buccal corridors. Following this trend, wider buccal corridors are more unesthetic.^{12,13}



Figure 22 - Different smile lines according to Tjan et al.²³ **A)** high smile, characterized by total exposure of clinical crowns and continuous strip of gingival tissue; **B)** medium smile, characterized by great (75%) or total (100%) exposure of clinical crowns and interdental or interproximal papillae; **C)** low smile, characterized by clinical crown exposure not greater than 75% and no gingival tissue.



Figure 23 - Clinical case illustrating gingival smile treatment: **A)** initial smile; **B)** orthodontic treatment outcome, illustrating ideal incisal design; and **C)** final smile.

Indeed, when this feature is compared to all the aforementioned ones, we come to the conclusion that one's buccal corridor is not as critical to smile esthetics. In spite of that, the 7th commandment suggests that intermediate buccal corridors are ideal, followed by narrow or nonexistent ones. Thus, cases of wide buccal corridors require rapid maxillary expansion and/or dental expansion so as to enhance smile esthetics.

Summary of the 7th commandment

- » Buccal corridor is not critical in smile esthetics.
- » Intermediate buccal corridor is more attractive, whereas wide buccal corridor (narrow smile arch) is more unesthetic.
- » Wide buccal corridor should be avoided and maxillary expansion should be indicated whenever necessary.

8th commandment — Midline and tooth angulation

Similarly to the buccal corridor, midline deviation plays a controversial role in smile esthetics. However, it is hardly noticed by laypeople. According to the literature, midline deviations not greater than 3–4 mm are not identified by laypeople.^{11,14} This explains why even though some famous artists and models have severe midline deviation, they are still considered as role models of beauty.

While midline deviations are hardly noticed by laypeople, changes in tooth angulation in the esthetic zone (alone or in combination) are extremely deleterious to one's smile. According to the literature,¹⁴ minimal changes of 2.0 mm in angulation of anterior teeth in frontal view are considered unesthetic by laypeople. For this reason, they must be corrected. Correction of angular discrepancies must be based on classic esthetic literature guidance: The incisal



Figure 24 - Different types of buccal corridor: A) buccal corridor at smiling; B) wide buccal corridor; C) intermediate buccal corridor; and D) narrow buccal corridor.

edge line of central incisors must be parallel to the interpupillary line.^{7,8,9} Additionally, incisor torque, especially central incisors, must change in lateral smile view, given that from this point of view, smile esthetics is analyzed differently in comparison to frontal view (Fig 25). Thus, changes in incisor angulation must be investigated from frontal as well as lateral smile view.

Figure 26 shows a case with both problems: Midline deviation and changes in tooth angulation in the esthetic zone. One can easily notice that correcting the second is prioritized over the first. Mini-implant was used to correct changes in tooth angulation. Additionally, once parallelism between the incisal edge line of central incisors and interpupillary line was restored, esthetic benefits were evinced.

Although the literature determines a limit of perception of 3–4 mm for laypeople to identify midline deviation and 2.0 mm to identify changes in tooth angulation, the 8th commandment suggests that midline deviations equal to or greater than 2.0 mm and any degree of changes in tooth angulation must be corrected.

Summary of the 8th commandment

- » Midline deviation is less relevant than changes in tooth angulation in the esthetic zone.
- » Midline deviation equal to or greater than 2.0 mm and any degree of changes in tooth angulation must be corrected.



Figure 25 - Importance of assessing incisor angulation in lateral view: A) ideal torque; B) oblique radiograph; and C) perpendicular radiograph.



Figure 26 - Clinical case illustrating the negative impact of changes in incisor angulation in frontal view: **A)** initial frontal photograph and smile photograph; **B)** intermediate result after incisal plane and angulation correction with the aid of mini-implant.

9th commandment — Tooth color and anatomical shape

Procedures comprising this commandment are usually performed in the orthodontic finishing phase. The 9th commandment basically determines three procedures to aid esthetic refinement: a) Dental bleaching; b) Adjustment of contacts; c) Reshaping of incisal edges in the esthetic zone.

Figure 27A shows a case of orthodontic finishing. This example casts doubt on the following: What is missing in this case? A closed-up view of teeth in the esthetic zone reveals the presence of black triangles and absence of papillae in interproximal spaces (Fig 27B). Papillae must fill interdental spaces up to the contacts. However, when contacts are inappropriate, interdental spaces might remain. Papilla/contact relationship in central incisors is of 1:1, for this reason, interdental space is half occupied by the papilla

and half occupied by contact (Fig 28).²⁸ Thus, interproximal wear was carried out to position the contact in the mid portion of clinical crowns, thereby favoring closing of black triangles and ideally filling the papillae (Fig 27C). With a view to enhancing incisal edges contour, slight wear was also carried out to minimize incisal embrasures, thus improving esthetics and giving the smile a younger look (Figs 27C and 29).

Summary of the 9th commandment

- » Dental bleaching is highly indicated to improve final results.
- » Contact adjustments are necessary to correct potential black spaces'.
- » Enameloplasty by means of enamel wear or veneer placement to enhance incisal design esthetics.



Figure 27 - Clinical case illustrating the importance of detailing and tooth anatomical shape: **A)** orthodontic finishing phase; **B)** closed-up view of the esthetic zone showing black triangles caused by inappropriate contact; **C)** final results after teeth reshaping.

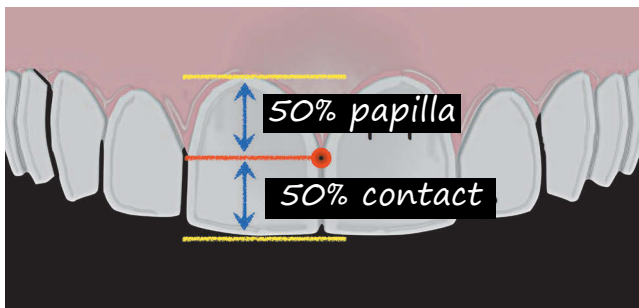


Figure 28 - Diagram illustrating the ideal position of contact between central incisors so as to favor filling of interproximal spaces by interdental papillae.

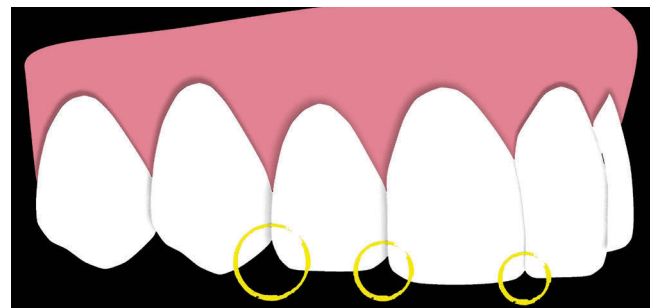


Figure 29 - Diagram illustrating the ideal disposition of incisal embrasures, showing a natural and progressive increase from central incisors to canines.

10th commandment — Lip volume

The last commandment is related to the structure that frames the smile: the lips. The current standard of beauty comprises not only a beautiful smile, but also voluminous lips and greater maxillary incisor exposure at smiling, at rest or while speaking.

According to the literature, anteroposterior positioning of teeth plays a key role in determining lip volume.^{5,30} As an example, Figures 30 and 31 show a 38-year-old patient with deep bite and severe reduction in lip vermilion exposure. Once deep bite and incisor proclination (particularly of lower incisors) were

corrected, there were significant improvements in lip volume, thereby enhancing lip esthetics and giving the patient a younger look. Importantly, in spite of severe deep bite, intrusion of maxillary teeth was not carried out to prevent smile aging. Teeth retraction must be carefully considered, since lip volume may decrease, thereby resulting in thinner unesthetic lips.

Orthodontists may also recommend multidisciplinary treatment carried out by means of filling agents for lip augmentation. This theme has been extensively discussed and, for this reason, we recommend further reading on the topic.^{5,30}



Figure 30 - Case report illustrating increased lip volume after orthodontic treatment: **A)** initial; **B)** final; **C)** initial profile showing thin lips; and **D)** final profile showing increased lip volume.

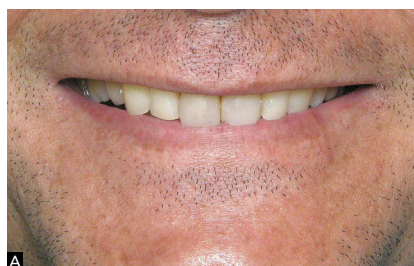


Figure 31 - Clinical case shown in Figure 30: **A)** initial smile; and **B)** final smile.

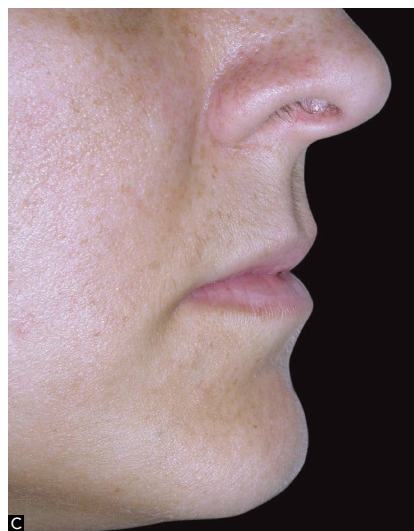
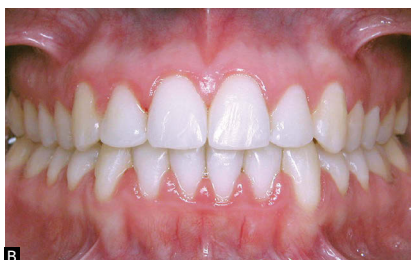


Figure 32 - Clinical case illustrating multidisciplinary treatment associating Orthodontics and Dermatology to correct smile and lip volume: **A)** initial; **B)** final; **C)** initial profile showing thin lips; and **D)** final profile showing increased lip volume after using filling agents for lip augmentation.



Figure 33 - Clinical case shown in Figure 32: **A)** initial smile; and **B)** final smile showing esthetic benefits produced by multidisciplinary treatment.

As an example of filling agents for lip augmentation, Figures 32 and 33 show a case of mild crowding with unpleasant smile and thin lips. Orthodontic treatment and dermatological procedures carried out by means of filling with hyaluronic acid yielded satisfactory results with a pleasant smile and greater lip volume, thereby fulfilling the 10th commandment (lip volume).

Summary of the 10th commandment

- » Voluminous lips are the current standard of beauty.
- » Care should be taken when performing retraction of anterior teeth so as to prevent negative impact over lip volume.
- » Multidisciplinary treatment associating Dentistry and Dermatology is necessary for lip filling, when needed.

FINAL CONSIDERATIONS

The 10 Commandments of smile esthetics may be considered a starting point for clinicians who aim at achieving maximum esthetic in dental treatment. Special attention should be given to the first four commandments associated with dominance of central incisors at smiling.

Importantly, treatment should be discussed with patients so as to individualize treatment planning and, as a result, fulfill their desires. Lastly, interdisciplinary treatment, i.e. teamwork, is vital to yield ideal esthetic outcomes.

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<http://www.ncbi.nlm.nih.gov/books/NBK988/>.

1. Authors

- The number of authors is unlimited; however, articles with more than four authors must inform the participation of each one of them in the study.

2. Title page

- Must comprise the title, abstract and keywords.
- Don't include information about the authors (e.g., authors' full names, academic degrees, institutional affiliations and administrative positions). They should be included only in the specific fields of the site for article submission. Thus, this information will not be available to reviewers.

3. Abstract

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

4. Text

- The text must be organized in the following sections: Introduction, Materials and Methods, Results, Discussion, Conclusions, References and Figure legends.
- Texts must contain no more than 4,000 words, including captions, abstract and references.
- Figures and tables must be submitted in separate files (see below).
- Insert the Figure legends also in the text document to help with the article layout.

5. Figures

- Digital images must be in JPG or TIF, CMYK or grayscale, at least 7 cm wide and 300 dpi resolution.
- Images must be submitted in separate files.
- In the event that a given illustration has been published previously, the legend must give full credit to the original source.
- The author(s) must ascertain that all figures are cited.

6. Charts and cephalometric tracings

- Files containing the original versions of graphs and tracings must be submitted.
- It is not recommended that such graphs and tracings be submitted only in bitmap image format (non-editable).
- Drawings may be improved or redrawn by the journal's production department at the criterion of the Editorial Board.
- Graphics must be cited in the text as Figures.

7. Tables

- Tables must be self-explanatory and should supplement, not duplicate the text.
- Must be numbered with Arabic numerals in the order they are mentioned in the text.
- A brief title must be provided for each table.
- In the event that a table has been published previously, a footnote must be included giving credit to the original source.
- Tables must be submitted as text files (Word or Excel, for example) and not in graphic format (non-editable image).

8. Ethics committees

- Articles must, where appropriate, refer to opinions of the Ethics Committees.

9. Required statements

- All manuscripts must be accompanied with the following statements, to be filled at the time of submission of the article:
- **Assignment of Copyright**
Transferring all copyright of the manuscript for Dental Press International if it is published.
 - **Conflict of Interest**
If there is any commercial interest of the authors in the research subject of the paper, it must be informed.
 - **Human and Animals Rights Protection**
If applicable, inform the implementation of the recommendations of international protection entities and the Helsinki Declaration, respecting the ethical standards of the responsible committee on human /animal experimentation.
 - **Permission to use copyrighted images**
Original illustrations or tables, or modified from copyrighted material must be accompanied by permission to be used, given by the owners of those rights and the original author (and the legend must give proper credit to the source).
 - **Informed Consent**
Patients have a right to privacy that should not be violated without informed consent.

10. References

- All articles cited in the text must appear in the reference list.
- All listed references must be cited in the text.
- For the convenience of readers, references must be cited in the text by their numbers only.
- References must be identified in the text by superscript Arabic numerals and numbered in the order they are mentioned in the text.
- Journal title abbreviations must comply with the standards of the "Index Medicus" and "Index to Dental Literature" publications.
- Authors are responsible for reference accuracy, which must include all information necessary for their identification.
- References must be listed at the end of the text and conform to the Vancouver Standards (http://www.nlm.nih.gov/bsd/uniform_requirements.html).
- The following examples should be used:

Articles with one to six authors

Sterrett JD, Oliver T, Robinson F, Fortson W, Knaak B, Russell CM. Width/length ratios of normal clinical crowns of the maxillary anterior dentition in man. *J Clin Periodontol*. 1999 Mar;26(3):153-7.

Articles with more than six authors

De Munck J, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M, et al. A critical review of the durability of adhesion to tooth tissue: methods and results. *J Dent Res*. 2005 Feb;84(2):118-32.

Book chapter

Higuchi K. Osseointegration and orthodontics. In: Branemark PI, editor. *The osseointegration book: from calvarium to calcaneus*. 1. Osseointegration. Berlin: Quintessence Books; 2005. p. 251-69.

Book chapter with editor

Breedlove GK, Schorffheide AM. Adolescent pregnancy. 2nd ed. Wiczorek RR, editor. White Plains (NY): March of Dimes Education Services; 2001.

Dissertation, thesis and final term paper

Kuhn RJ. Force values and rate of distal movement of the mandibular first permanent molar. [Thesis]. Indianapolis: Indiana University; 1959.

Digital format

Oliveira DD, Oliveira BF, Soares RV. Alveolar corticotomies in orthodontics: Indications and effects on tooth movement. *Dental Press J Orthod*. 2010 Jul-Aug;15(4):144-57. [Access 2008 Jun 12]. Available from: www.scielo.br/pdf/dpjo/v15n4/en_19.pdf.

1. Registration of clinical trials

Clinical trials are among the best evidence for clinical decision making. To be considered a clinical trial a research project must involve patients and be prospective. Such patients must be subjected to clinical or drug intervention with the purpose of comparing cause and effect between the groups under study and, potentially, the intervention should somehow exert an impact on the health of those involved.

According to the World Health Organization (WHO), clinical trials and randomized controlled clinical trials should be reported and registered in advance.

Registration of these trials has been proposed in order to (a) identify all clinical trials underway and their results since not all are published in scientific journals; (b) preserve the health of individuals who join the study as patients and (c) boost communication and cooperation between research institutions and with other stakeholders from society at large interested in a particular subject. Additionally, registration helps to expose the gaps in existing knowledge in different areas as well as disclose the trends and experts in a given field of study.

In acknowledging the importance of these initiatives and so that Latin American and Caribbean journals may comply with international recommendations and standards, BIREME recommends that the editors of scientific health journals indexed in the Scientific Electronic Library Online (SciELO) and LILACS (Latin American and Caribbean Center on Health Sciences) make public these requirements and their context. Similarly to MEDLINE, specific fields have been included in LILACS and SciELO for clinical trial registration numbers of articles published in health journals.

At the same time, the International Committee of Medical Journal Editors (ICMJE) has suggested that editors of scientific journals require authors to produce a registration number at the time of paper submission. Registration of clinical trials can be performed in one of the Clinical Trial Registers validated by WHO and ICMJE, whose addresses are available at the ICMJE website. To be validated, the Clinical Trial Registers must follow a set of criteria established by WHO.

2. Portal for promoting and registering clinical trials

With the purpose of providing greater visibility to validated Clinical Trial Registers, WHO launched its Clinical Trial Search Portal (<http://www.who.int/ictrp/network/en/index.html>), an interface that allows simultaneous searches in a number of databases. Searches on this portal can be carried out by entering words, clinical trial titles or identification number. The results show all the existing clinical trials at different stages of implementation with links to their full description in the respective Primary Clinical Trials Register.

The quality of the information available on this portal is guaranteed by the producers of the Clinical Trial Registers that form part of the network recently established by WHO, i.e., WHO Network of Collaborating Clinical Trial Registers. This network will enable interaction between the producers of the Clinical Trial Registers to define best practices and quality control. Primary registration of clinical trials can be performed at the following websites: www.who.int/ictrp

(www.who.int/ictrp) (Australian Clinical Trials Registry), www.clinicaltrials.gov and <http://isrctn.org> (International Standard Randomized Controlled Trial Number Register (ISRCTN)). The creation of national registers is underway and, as far as possible, the registered clinical trials will be forwarded to those recommended by WHO.

WHO proposes that as a minimum requirement the following information be registered for each trial. A unique identification number, date of trial registration, secondary identities, sources of funding and material support, the main sponsor, other sponsors, contact for public queries, contact for scientific queries, public title of the study, scientific title, countries of recruitment, health problems studied, interventions, inclusion and exclusion criteria, study type, date of the first volunteer recruitment, sample size goal, recruitment status and primary and secondary result measurements.

Currently, the Network of Collaborating Registers is organized in three categories:

- Primary Registers: Comply with the minimum requirements and contribute to the portal;
- Partner Registers: Comply with the minimum requirements but forward their data to the Portal only through a partnership with one of the Primary Registers;
- Potential Registers: Currently under validation by the Portal's Secretariat; do not as yet contribute to the Portal.

3. Dental Press Journal of Orthodontics -

Statement and Notice

DENTAL PRESS JOURNAL OF ORTHODONTICS endorses the policies for clinical trial registration enforced by the World Health Organization - WHO (<http://www.who.int/ictrp/en/>) and the International Committee of Medical Journal Editors - ICMJE (# <http://www.wame.org/wamestmt.htm#trialreg> and http://www.icmje.org/clin_trialup.htm), recognizing the importance of these initiatives for the registration and international dissemination of information on international clinical trials on an open access basis. Thus, following the guidelines laid down by BIREME / PAHO / WHO for indexing journals in LILACS and SciELO, DENTAL PRESS JOURNAL OF ORTHODONTICS will only accept for publication articles on clinical research that have received an identification number from one of the Clinical Trial Registers, validated according to the criteria established by WHO and ICMJE, whose addresses are available at the ICMJE website <http://www.icmje.org/faq.pdf>. The identification number must be informed at the end of the abstract.

Consequently, authors are hereby recommended to register their clinical trials prior to trial implementation.

Yours sincerely,

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