Dental Press Journal of
ORTHODONTICS

Volume 26 - Number 2 - Online

ORTHODONTICS HIGHLIGHTS

https://doi.org/10.1590/2177-6709.26.2.e21hig2

Matheus Melo **PITHON**[1] ✉

https://orcid.org/0000-0002-8418-4139

Submitted: March 10, 2021 • **Revised and accepted:** March 24, 2021

✉ matheuspithon@gmail.com

LOW-POWER LASER INCREASES THE STABILITY OF MINI-IMPLANTS

When thinking about orthodontic anchorage, orthodontic mini-implants are considered to be water dividers. Obtaining absolute anchorage with low patient collaboration was only achieved as a result of its development. Despite the many advantages of mini-implants, they are limited in terms of their instability. The stability of mini-implants to bone depends on several factors, such as bone density and thickness of the insertion site, device surface morphology, surgical technique, and the physiological repair process. Recent studies have shown that low-power lasers have promising effects on orthodontics, accelerating orthodontic movement, reducing pain after orthodontic activation, and increasing the stability of orthodontic mini-implants. However, there is still no consensus on whether low-power lasers have been able to

(1) Universidade Estadual do Sudoeste da Bahia, Disciplina de Ortodontia (Jequié/BA, Brazil). (2) Universidade Federal do Rio de Janeiro, Programa de Pós-Graduação em Odontopediatria e Ortodontia (Rio de Janeiro/RJ, Brazil).

overcome the issue of stability. For this reason, Brazilian researchers carried out a systematic review with meta-analysis[1] that aimed to evaluate the effects of low-power laser therapy on the stability of mini-implants. An unrestricted search was performed in the following electronic databases: PubMed, Science Direct, Embase, Scopus, Web of Science, Cochrane Library, LILACS, Google Scholar and ClinicalTrials.gov. Randomized clinical trials (RCTs), or non-randomized clinical trials (non-RCTs) that assessed the effects of low-power laser on IMO stability, were included. The authors concluded with this study that the low-power laser has clinical applicability to increase the stability of mini-implants. However, the authors emphasize the need for high-quality clinical trials to explain the real effects of this therapy.

INSTAGRAM AS A MARKETING TOOL FOR ORTHODONTISTS

Before the widespread use of the internet, orthodontists attracted patients through word of mouth and/or referral from other professionals. With the advancement of cyberculture, the internet has become a key promotional tool. However, doubts have been raised regarding professional exposure on social networks. A group of Brazilian researchers developed a study[2] with the aim of analyzing the public's perception of professional credibility, and the desire to become a customer, based on images posted by orthodontists on Instagram.

The study was conducted using a self-administered digital questionnaire based on images from public Instagram profiles (Fig 1) of orthodontists, found by using certain hashtags. The themes of the posts were analyzed using a qualitative analysis, and the results were expressed in categories. Based on the results obtained, the authors concluded that Instagram is a social network widely used by patients, dental professionals, and dental students, to seek health services. The difference between these groups regarding the perception of professional credibility portrayed by orthodontists is included in this study.

Figure 1: Instagram social network.

COMFORT IS A KEY FACTOR FOR PATIENTS WHEN CHOOSING THE TYPE OF ORTHODONTIC APPLIANCE

The search for orthodontic correction has been growing year after year. The aesthetic appeal, as well as the comfort of orthodontic appliances, are considered to be important factors of this trend. Currently, there is a multitude of orthodontic appliances, ranging from thermoplastic aligners to metal brackets glued to the teeth. The patient's preference for one specific type of appliance is a difficult issue to assess, since this can be influenced not only by factors directly related to orthodontic therapy, but also by subjective factors of the individual, such as previous experiences, attitudes, or beliefs about treatment. Some studies have tried to determine the motivations that lead patients to undergo orthodontic treatment, however, little is known about the reasons that influence their preferences for the available devices and how orthodontists could use this information to identify treatments for each patient. Based on this assumption, a Brazilian research group, headed by a Peruvian researcher, developed a study[3] that aimed to evaluate the reasons that influence the preferences of a certain type of orthodontic appliance in relation to another, among patients and orthodontists. To carry out this study, patients and orthodontists answered a questionnaire associated with a set of images containing an image of the same patient using aligners;

lingual, polycrystalline, monocrystalline or buccal metallic brackets (Fig 2). The results obtained with the study revealed that patients care more about comfort and quality of life when using brackets, whereas orthodontists are more concerned with results and clinical performance.

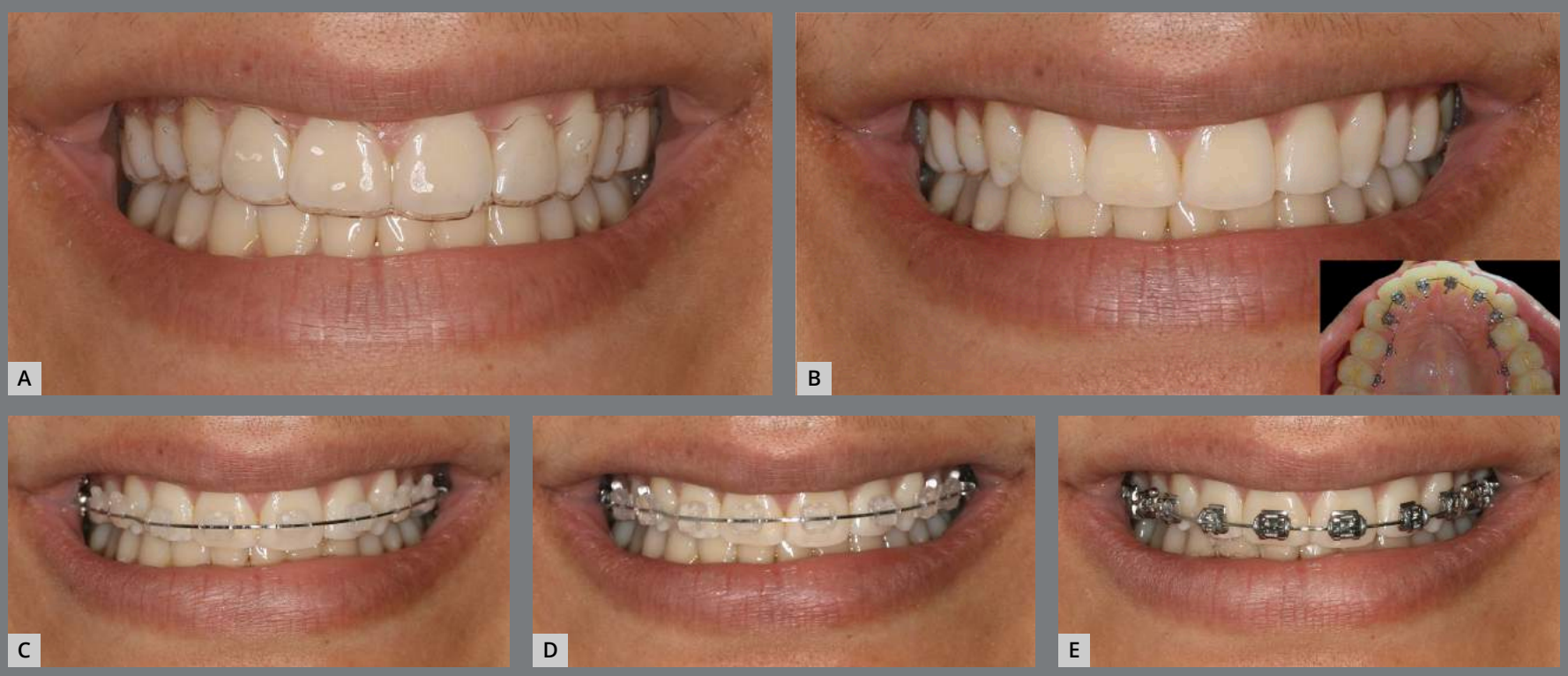


Figure 2: Images of the orthodontic appliances presented to the participants: **A)** Clear aligners; **B)** Lingual metallic brackets.; **C)** Polycrystalline ceramic brackets; **D)** Monocrystalline ceramic brackets; and **E)** Buccal metallic brackets. Source: Maranon-Vasquez et al.[3], 2021.

INSTAGRAM AS A TOOL THAT GUIDES PATIENTS REGARDING ORTHODONTIC CONTENT

The Internet has had a transforming effect on the way the world interacts and accesses information. However, health information on the Internet is not regulated. This means that online health information, including information shared on social media, may not be accurate or based on evidence. One of the most popular social media platforms, with around one billion users worldwide, is Instagram, a networking service that lets users share or "post" texts, images, and videos. Instagram can support orthodontists, by helping them to disseminate important topics to increase patients' knowledge. However, if misused it can have a negative impact. Considering this theme, Australian researchers developed a study[4] that aimed to evaluate and compare the content of posts on Instagram by patients and professionals who practice orthodontics, in relation to orthodontic retention. To do this, hashtags related to orthodontic retention were searched. Patients' posts were also qualitatively assessed. The results led the authors to conclude that professionals use Instagram more frequently than patients to post information related to orthodontic retention. It can also be seen that the content of Instagram posts differed between professionals and patients.

EXCESSIVE CONSUMPTION OF SALT IN THE DIET ACCELERATES ORTHODONTIC TOOTH MOVEMENT

The consumption of salt in the diet of most people in Western countries is still about twice the amount recommended in the guidelines proposed by the World Health Organization (WHO). Excessive consumption of salt is associated with several diseases such as hypertension and osteopenia. Sodium and chloride are the chemical components of salt. There is evidence that the local sodium content changes in various tissues in response to the consumption of salt in the diet influences the activity of immune cells, such as macrophages and T cells, and impairs osteoclastogenesis. Based on this, it can be assumed that the sodium content in the periodontal ligament could influence the inflammatory reaction induced by orthodontic tooth movement (OTM). German researchers developed a study[5] in order to test this hypothesis. For this purpose, an animal model with mice was used, where the expression of genes involved in bone metabolism, periodontal bone loss, OTM and bone density were analyzed. The results of the study led the authors to conclude that diets containing salt accelerate orthodontic tooth movement and promote periodontal bone loss due to reduced bone density, which can be attributed to increased osteoclast activity.

REFERENCES

1. Costa ACF, Maia TAC, de Barros Silva PG, Abreu LG, Gondim DV, Santos PCF. Effects of low-level laser therapy on the orthodontic mini-implants stability: a systematic review and meta-analysis. Prog Orthod. 2021 Feb 15;22(1):6.

2. Meira TM, Prestes J, Gasparello GG, Antelo OM, Pithon MM, Tanaka OM. The effects of images posted to social media by orthodontists on public perception of professional credibility and willingness to become a client. Prog Orthod. 2021 Mar 8;22(1):7.

3. Maranon-Vasquez GA, Barreto L, Pithon MM, Nojima LI, Nojima M, Araujo MTS, et al. Reasons influencing the preferences of prospective patients and orthodontists for different orthodontic appliances. Korean J Orthod. 2021 Mar 25;51(2):115-25.

4. Meade MJ, Dreyer CW. What's in a hashtag: A content evaluation of Instagram posts related to orthodontic retention and retainers. J World Fed Orthod. 2021 Mar;10(1):35-9.

5. Schröder A, Gubernator J, Leikam A, Nazet U, Cieplik F, Jantsch J, et al. Dietary Salt Accelerates Orthodontic Tooth Movement by Increased Osteoclast Activity. Int J Mol Sci. 2021 Jan 9;22(2):596.

Dental Press Journal of
ORTHODONTICS

Volume 26 - Number 2 - Online

ORTHODONTIC INSIGHT

https://doi.org/10.1590/2177-6709.26.2.e21ins2

Orthodontic treatment pause during COVID-19 outbreak: Are we overlooking potential harms to our patients and their treatment outcomes?

Feras **ABED AL JAWAD**[1] ✉
https://orcid.org/0000-0002-9535-9678

Najah **ALHASHIMI**[1,2]
https://orcid.org/0000-0002-9424-8028

Submitted: June 07, 2020 • **Revised and accepted:** March 01, 2021

✉ ferasjawad@gmail.com

How to cite: Abed Al Jawad F, Alhashimi N. Orthodontic treatment pause during COVID-19 outbreak: Are we overlooking potential harms to our patients and their treatment outcomes? Dental Press J Orthod. 2021;26(2):e21ins2.

(1) Orthodontics Section, Hamad Dental Center, Hamad Medical Corporation (Doha, Qatar).
(2) College of Dental Medicine, Qatar University (Doha, Qatar).

ABSTRACT

Introduction: The global outbreak of coronavirus disease 2019 (COVID-19) has led all dental governing bodies across the world to minimize or cancel routine/elective dental procedures and limit dental services to only acute emergency situations. Orthodontic treatment is a long-term treatment that necessitates several appointments. However, if patients are left unsupervised during this pandemic, serious harms might arise apart from acute orthodontic emergencies.

Objective: In this article we highlight these harms and their negative impact on patients and the overall success of their treatment.

Conclusion: We briefly presented actions needed to be undertaken by orthodontists to gradually allow for recalling patients according to the stage of their treatment to avoid any potential harms to the treatment outcome and avoid any subsequent medicolegal consequences.

Keywords: COVID-19. Orthodontic treatment. Harm.

RESUMO

Introdução: O surto global do coronavírus 2019 (COVID-19) levou todos os órgãos diretivos de Odontologia, ao redor do mundo, a minimizar ou cancelar procedimentos odontológicos de rotina/eletivos e limitar os serviços odontológicos apenas a situações de emergência aguda. O tratamento ortodôntico é um tratamento de longa duração que requer várias consultas. No entanto, se os pacientes não forem supervisionados durante essa pandemia, danos graves podem surgir, além das emergências ortodônticas.

Objetivo: No presente trabalho, destacamos esses danos e seu impacto negativo nos pacientes e no sucesso geral de seus tratamentos.

Conclusão: Foram apresentadas, resumidamente, as ações que devem ser realizadas pelos ortodontistas para gradualmente retomar o atendimento dos pacientes, conforme o estágio de seu tratamento, para evitar quaisquer danos potenciais ao desfecho do tratamento e evitar quaisquer consequências médico-legais subsequentes.

Palavras-chave: COVID-19. Tratamento ortodôntico. Dano.

INTRODUCTION

The global outbreak of coronavirus disease 2019 (COVID-19) has dramatically changed the world in all aspects. This has led the World Health Organization (WHO) to declare this disease outbreak as a global pandemic.[1]

The common mode of COVID-19 transmission is either by respiratory droplets or contact routes. As a result, guidelines for healthcare workers started to emerge in an attempt to prevent COVID-19 transmission.[2,3] In the dental profession, it is well known that dental procedures produce aerosols and droplets that pose real risk of disease transmission. Furthermore, coronavirus can remain suspended in the air for longer periods and can contaminate surfaces and instruments that can lead to indirect transmission.[4]

The fact that dental practices are focal points for cross-infection has led all dental governing bodies across the world to minimize or cancel routine/elective dental care, and limit services to only acute emergency situations, relying on telecommunication, pharmaceutical options, the use of high-volume saliva ejectors and avoid the use of aerosol-generating procedures or any procedure that can stimulate coughing. In addition, guidelines have been published during this pandemic to maximize personal protection equipment (PPE) in an effort to reduce the risk of COVID-19 transmission.[2]

Although several vaccines have been recently introduced, it is not known how long COVID-19 will last, given the fact that little is known with respect to its characteristics. Furthermore, there is no effective treatment or medication for this disease, until now, that can aid in reducing severe complications or mortality rate. This in turn, will have negative long-term implications on patients whose care involves several appointments, such as orthodontic patients, who are at the moment experiencing delays in their routine follow-ups.

A recent review summarized advice that can be provided to patients for the short-term management of orthodontic emergencies. Among recommendations presented, were: treatment advice should be delivered first remotely and, only when necessary, in-person treatment can be given, provided strict infection control protocols are implemented.[5]

However, there are other problems that might arise, in addition to acute orthodontic emergencies, which may lead to different types of harm, with respect to treatment outcomes. Such problems are related to the stage of treatment, whether in active or passive phases of orthodontic treatment, and require an urgent need to be highlighted in this unprecedented situation. Therefore, the aim of the present paper is twofold. Firstly, to highlight harms that might arise, other than acute

orthodontic emergencies, in unsupervised orthodontic cases, due to global suspension or delay of routine orthodontic follow-ups during the COVID-19 outbreak. Secondly, to briefly present actions needed to be undertaken by orthodontists to gradually allow for recalling patients, according to the stage of their treatment, to avoid any future potential harms to the final treatment outcome.

1. HARMS RELATED TO UNSUPERVISED ORTHODONTIC PATIENTS

Orthodontic treatment is a long-term treatment that necessitates several appointments on a monthly basis or sometimes less, depending on the type of appliance used. To achieve successful treatment outcomes, orthodontists should conduct comprehensive examination, give accurate diagnosis and plan treatment steps efficiently. In addition, every effort should be made to protect the health of both hard and soft oral tissues and the psychological well-being of the patient from any harm.[6,7]

The WHO defines patient harm as “an incident that results in harm to a patient, such as impairment of structure or function of the body and/or any deleterious effect arising there from or associated with plans or actions taken during the provision of healthcare, rather than an underlying disease or injury, and

may be physical, social or psychological (e.g., disease, injury, suffering, disability and death)".[8] Although harms and complications related to orthodontic treatment are not life-threatening and less severe than other medical interventions, it is well reported that they might cause functional, social and psychological impairments to patients.[9] From an ethical point of view, orthodontists should be aware of all risks expected, and should inform their patients about them including those that are not under the control of the clinician, such as the disruptions of routine orthodontic follow-ups. In addition to adverse effects on patients' treatment outcomes, disruptions in follow-ups can lead to financial burdens of the whole healthcare system providing any type of medical or dental care.

During the outbreak of COVID-19, several guidelines and recommendations were published with respect to dealing with acute orthodontic emergencies, with no mention of other potential harms that might arise due to unsupervised orthodontic cases. Here, we present examples of potential harms that orthodontists should be aware of to prevent future failure of orthodontic treatment.

1.1 HARMS RELATED TO THE UNSUPERVISED MECHANICS FOR TOOTH MOVEMENT

Depending on the stage of treatment, unwanted tooth movement can occur as a result of prolonged period of time without monitoring or adjustments. Unwanted tooth movement can take place in several situations. In extraction cases, if teeth are left without monitoring, space loss is inevitable. Applying orthodontic forces, such as those used for retraction of teeth, torqueing, impacted teeth traction, intrusion, or any other type of tooth movement, if left unsupervised, can lead to serious harms to teeth and associated supporting periodontal tissues. These may include cortical bone perforations, placing teeth in unfavorable position, root resorption and severe tooth rotation and mobility.[10] This in turn, will jeopardize the treatment goals and will have a negative impact on the final treatment outcome. Therefore, patients who are in an active stage of orthodontic treatment should be evaluated and monitored carefully and be given priority to be seen with high sense of urgency. Clinicians should weight the potential benefits of recalling patients, and the risks of contracting an infection, such as COVID-19, and patients should be informed and involved in the decision making.

1.2 HARMS RELATED TO FINISHED TREATMENT

Retention is one of the most important stages of orthodontic treatment. The aim of this stage is to maintain the stability of the corrected occlusion, as teeth have inherent tendency to return to their original positions.[11] Retention can be achieved by either fixed or removable retainers. Therefore, careful monitoring, adjustment and assessment of retainers should continue post-treatment, to prevent relapse. It is not uncommon to experience problems related to retainers with respect to patients' compliance, breakages or losing them.[12] Usually, the patient is instructed to report any problems related to retainers as soon as they occur. However, during this pandemic, and due to the current regulations, problems related to retainers are not considered an urgent situation that necessitates immediate care. As a result, relapse will take place, with variations in severity depending on the type of malocclusion before treatment. This will lead to serious psychological harm to the patient after complying with long-term treatment and incurring all financial expenses. On the other hand, this will frustrate the orthodontist and will lead to extra treatment time, depending on the extent of the problem. Therefore, problems related to retainers during the COVID-19 outbreak should be regarded as an urgent need for care and be given priority, in order to prevent any sort of relapse.

1.3 PSYCHOLOGICAL HARMS ON PATIENTS

The global outbreak of COVID-19 has imposed changes to our behaviors and the way we interact with the outside world. Restricted access to healthcare facilities is among the important changes that people have to cope with. Unless an emergency situation is present, patients cannot continue with their routine medical or dental follow ups. This issue might lead to distress, panic and immense pressure on patients, in particular, orthodontics patients. The fact that orthodontic follow-ups are discontinued during this outbreak has led many patients to question the progress of their treatment and whether any harm would happen for this long delay. In addition, several studies reported that patients who are undergoing orthodontic treatment will experience positive impact on their quality of life (QoL) during the course of treatment.[13] Such delay could lead to negative impact on their QoL that might affect their compliance to treatment and their overall expectations about the final outcome. Therefore, it is highly recommended during this pandemic to keep communicating with all patients, even in the absence of an emergency situation, to reduce their anxiety levels and build their confidence level for the coming future.

1.4 HARMS TO TEETH AND PERIODONTIUM

In addition to improving esthetics by correcting jaws relationship and abnormal teeth positions, orthodontists aid in creating a healthy environment to teeth and the supporting tissues. However, in some instances, orthodontic treatment can hold potential harm on the periodontal tissues. This complication could be aggravated if the patient is left unsupervised for long time. Unwanted tooth movements, as mentioned earlier, or not following strict and rigorous oral hygiene measures due to the long wait can lead to periodontal problems and demineralization of teeth — especially in teenagers, who constitute the majority of orthodontic patients.[14] Therefore, every effort should be made for oral hygiene reinforcement, by contacting patients regularly either by calling them or sending letters or emails. Such practice will eliminate harm to teeth and the periodontium, and will reduce referrals to other dental disciplines, which will lead to fewer burdens on dental practices during this pandemic.

2. ACTIONS NEEDED TO BE UNDERTAKEN BY ORTHODONTISTS TO GRADUALLY ALLOW FOR RECALLING PATIENTS, TO PREVENT FAILURE OF TREATMENT AND AVOID ANY MEDICO-LEGAL CONSEQUENCES

What if the patient experienced any type of harm, previously mentioned, and decided to file an official complaint or a lawsuit to the regulatory governing body? Who is to blame? Most Healthcare professionals, including orthodontists, suspended

or minimized routine/elective medical interventions, based on international guidelines and recommendations from the WHO and the state/local health regulatory authorities. The dilemma every clinician is facing at the moment is what type of harms, not related to acute emergency situations, are expected, and could they be prevented? This should be balanced against the risk of contracting a pandemic disease such as COVID-19. According to the American Association of Orthodontics (AAO) recent statement:[15] "The AAO recommends that its members follow all applicable federal, provincial, state and local authorities' guidance concerning closure recommendations for non-emergency care. To that end, the AAO defines emergency orthodontic care as care that will relieve pain and/or infection, is trauma-related, or is critically necessary to prevent harm to the patient". This statement implies that, in addition to any type of physical harm the patient might experience, harm from other non-emergency situations should receive great deal of attention and immediate care.

Jerrold[16] summarized the actions needed to be taken after few months of orthodontic treatment suspension. He recommends that every orthodontist should do in-depth analysis of every patient record and prioritize patients to be recalled according to the stage of orthodontic treatment. Patients who are under active orthodontic forces that have the potential to move teeth beyond where planned should be recalled,

whereas patients in passive stage of treatment or in the retention phase can wait, as harm to them is unexpected. It is down to the judgment of the clinician to assess and evaluate the risks that might arise if the patient is kept unsupervised and what is considered an urgent need for care.

In summary, and due to the fact that it is not known when this pandemic will end, the following actions should be considered and introduced, in addition to the current recommendations we apply in our orthodontic practices, to prevent any potential harms to both patients and treatment outcomes:

1. Comprehensive revision of all patients' records should be carried out, to develop a system that will classify them according to their stage of treatment. This will allow identifying patients who need to be seen urgently to prevent future harms, such as unwanted tooth movement or any damage to the retention protocol.

2. In line with the above, patients should be informed and educated about the potential harms they might experience with respect to the whole course of their treatment other than acute emergency situations. Risks related to the progress of their treatment if they are not recalled or risks related to contracting a disease, such as COVID-19, if they agree to be recalled should be clarified and documented.

Calling patients or using digital communication tools, such as videos, can aid in triaging patients and get a better insight about their current status. In addition, patients who are in a stage where any type of harm is unexpected should be assured and instructed to keep complying with treatment protocols, including oral hygiene maintenance. This in turn will reduce their anxiety levels during the pandemic and will boost their confidence towards the treatment and the whole healthcare system.

3. State/local health regulatory authorities should take their responsibilities to ensure effective healthcare provision during this pandemic. Among these responsibilities, protecting and defending healthcare professionals from any medico-legal issues that might arise due to suspension of routine and elective dental care, including orthodontic care. Furthermore, every effort should be made to support healthcare professionals in many respects. These include; providing them with the most up-to-date information related to COVID-19 outbreak, ensure the availability of personal protective equipment (PPE), provide regular testing for COVID-19 and give them freedom to judge every case based on the status of the patient, potential risks expected and the totality of circumstances.

CONCLUSIONS

Orthodontists should be aware of potential harms to treatment outcomes that might occur as a result of unsupervised orthodontic treatment, apart from acute emergency situations. It is not known how long COVID-19 outbreak will last, and therefore orthodontists should consider recalling patients who are in high need for care, depending on their stage of treatment. State/local health regulatory authorities should support and protect clinicians during this unprecedented situation, and patients should be informed and educated about all possible consequences. This in turn will avoid any medico-legal issues and will prevent any jeopardy to the final treatment outcomes.

AUTHORS' CONTRIBUTION

Feras Abed Al Jawad (FAAJ):

Najah Alhashimi (NA):

Conception or design of the study:

FAAJ, NA.

Data acquisition, analysis or interpretation:

FAAJ, NA.

Writing the article:

FAAJ.

Critical revision of the article:

FAAJ, NA.

Obtained funding:

FAAJ, NA.

Overall responsibility:

FAAJ.

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

REFERENCES

1. World Health Organization. WHO director-general's opening remarks at the media briefing on COVID-19. Available from: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020

2. Meng L, Hua F, Bian Z. Coronavirus disease 2019 (COVID-19): emerging and future challenges for dental and oral medicine. J Dent Res. 2020 May;99(5):481-7.

3. Ather A, Patel B, Ruparel NB, Diogenes A, Hargreaves KM. Coronavirus disease 19 (COVID-19): implications for clinical dental care. J Endod. 2020 May;46(5):584-95.

4. Van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Engl J Med. 2020 Apr;382(16):1564-67.

5. Suri S, Vandersluis YR, Kichhar AS, Bhasin R, Abdallah M. Clinical orthodontic management during the COVID-19 pandemic. Angle Orthod. 2020 Jul 1;90(4):473-84.

6. Antoun JS, Mei L, Farella M. Effect of orthodontic treatment on the periodontal tissues. Periodontol 2000. 2017 Jun;74(1):140-57.

7. Johal A, Alyaqoobi I, Patel R, Cox S. The impact of orthodontic treatment on quality of life and self-esteem in adult patients. Eur J Orthod. 2015 Jun;37(3):233-7.

8. World Health Organization. The conceptual framework for the International Classification for Patient Safety. 2009.

9. González MJ, Romero M, Peñacoba C. Psychosocial dental impact in adult orthodontic patients: What about health competence? Health Qual Life Outcomes. 2019 Jun;17(1):110.

10. Krishnan V. Critical issues concerning root resorption: a contemporary review. World J Orthod. 2005;6(1):30-40.

11. Littlewood SJ, Millett DT, Doubleday B, Bearn DR, Worthington HV. Orthodontic retention: a systematic review. J Orthod. 2006 Sep;33(3):205-12.

12. Shah N. Compliance with removable orthodontic appliances. Evid Based Dent. 2017 Dec;18(4):105-6.

13. Zhang M, McGrath C, Hägg U. Changes in oral health-related quality of life during orthodontic appliance treatment therapy. Am J Orthod Dentofacial Orthop. 2008 Jan;133(1):25-9.

14. Wishney M. Potential risks of orthodontic therapy: a critical review and conceptual framework. Aust Dent J. 2017 Mar;62 suppl 1:86-96.

15. American Association of Orthodontics. Breaking news: COVID-19 Resource Center. Available from: https://www1.aaoinfo.org/

16. Jerrold L. Exceptional circumstances. Am J Orthod Dentofacial Orthop. 2020 Apr;157(6):852-5.

Dental Press Journal of
ORTHODONTICS

Volume 26 - Number 2 - Online

ORIGINAL ARTICLE

https://doi.org/10.1590/2177-6709.26.2.e2119378.oar

Separation of aligning and leveling stages to control mandibular incisor inclination: A randomized clinical trial

Pornpat **THEERASOPON**[1]
https://orcid.org/0000-0002-3870-2791
Steven J. **LINDAUER**[2]
https://orcid.org/0000-0002-3202-7991
Chairat **CHAROEMRATROTE**[3] ✉
https://orcid.org/0000-0002-6305-9881

Submitted: December 15, 2019 • **Revised and accepted:** May 24, 2020

✉ metalbracket@hotmail.com

How to cite: Theerasopon P, Lindauer SJ, Charoemratrote C. Separation of aligning and leveling stages to control mandibular incisor inclination: A randomized clinical trial. Dental Press J Orthod. 2021;26(2):e2119378.

(1) University of Phayao, School of Dentistry, Department of Orthodontics (Phayao, Thailand). (2) Virginia Commonwealth University, School of Dentistry, Department of Orthodontics (Richmond/VA, USA). (3) Prince of Songkla University, Faculty of Dentistry, Department of Preventive Dentistry (Songkhla, Thailand).

ABSTRACT

Objective: To determine whether separating the alignment and leveling phases can reduce proclination of the mandibular incisors. **Methods:** Eligibility criteria included Class I subjects with an irregularity index of 3-5 mm, 3-4 mm curve-of-Spee (COS), and non-extraction treatment. Thirty adults were randomly allocated into two groups: (1) Control group was leveled and aligned simultaneously with flat archwires progressively to 0.016x0.022-in stainless-steel; (2) Experimental group was aligned first with 0.014-in-superelastic NiTi with mild accentuated COS, then leveled using 0.016x0.022-in beta-titanium accentuated COS archwires and gradually reduced the curve until flat. Mandibular incisor position and inclination were evaluated by cephalometric analysis. COS and irregularity index were evaluated in study models. Assessment was conducted twice after 0.016-in NiTi and after 0.016x0.022-in stainless-steel archwire placements. Dental changes from cephalograms and models were compared within group using paired *t*-test and between groups using independent *t*-test. **Results:** Control group: Round-wire-phase, mandibular incisors tipped labially (4.38° and 1 mm) with intrusion (-1.13 mm); Rectangular-wire-phase, mandibular incisors further intruded and proclined (-0.63 mm and 1.38°). Experimental group: During aligning with round accentuated COS archwires, mandibular incisors tipped very slightly labially (0.75° and 0.50 mm) with no significant intrusion; during leveling with rectangular archwires, incisors majorly intruded (1.75 mm) with slight proclination (1.81°). The experimental group had significant less incisor proclination (control: 5.76°, experimental: 2.56°) with more incisor intrusion (control: -1.75 mm, experimental: -2.13 mm). The COS in experimental group showed significant greater reduction (-2.88 mm) than that of the control group (-1.69 mm). **Conclusion:** In control group, mandibular incisor proclination was markedly observed in round archwires, with further proclination caused by rectangular archwires. In experimental group, minimal proclination was exhibited when accentuated COS round archwires were used for aligning. Leveling with rectangular archwires caused less proclination with more COS reduction.

Keywords: Leveling and alignment. Mandibular incisor proclination. Non-extraction orthodontic treatment.

RESUMO

Objetivo: Avaliar se separar os estágios de alinhamento e nivelamento reduz a projeção dos incisivos inferiores. **Métodos:** Os critérios de inclusão foram indivíduos Classe I com índice de irregularidade de 3-5mm, Curva de Spee (CS) de 3-4mm e tratamento sem extrações. Trinta adultos foram alocados aleatoriamente em dois grupos: o Grupo Controle (1) foi simultaneamente alinhado e nivelado com arcos planos progressivamente até atingir o 0,016" x 0,022" de aço inoxidável; o Grupo Experimental (2) foi inicialmente alinhado com arcos superelásticos NiTi 0,014" com CS levemente aumentada, em seguida nivelado com arcos de beta-titânio 0,016" x 0,022" com CS acentuada, que foi gradualmente reduzida até ficar plana. A posição e inclinação dos incisivos inferiores foram avaliadas por meio de análise cefalométrica. A CS e o índice de irregularidade foram avaliados por meio de modelos de estudo. A avaliação foi realizada duas vezes, sendo após a inserção dos arcos NiTi 0,016" e dos arcos 0,016" x 0,022" de aço. As mudanças dentárias visualizadas nos cefalogramas e nos modelos foram comparadas dentro dos grupos utilizando teste *t* pareado e entre os grupos utilizando o teste *t* independente. **Resultados:** Grupo Controle: estágio de arco redondo: os incisivos inferiores se inclinaram vestibularmente (4.38° e 1 mm) e intruíram (-1,13mm); estágio de arco retangular: os incisivos inferiores intruíram e se projetaram adicionalmente (-0.63mm e 1,38°). Grupo Experimental: Durante o alinhamento com arcos redondos e CS acentuada, os incisivos inferiores se inclinaram levemente para vestibular (0,75° e 0,50mm), sem intrusão significativa; durante o nivelamento com arcos retangulares, os incisivos, em sua maioria, intruíram (1,75mm), com uma leve projeção (1,81°). O grupo experimental apresentou projeção dos incisivos significativamente menor (controle: 5,76°; experimental: 2,56°), com maior intrusão dos incisivos (controle: -1,75mm; experimental: -2,13mm). A CS no Grupo Experimental apresentou redução significativamente maior (-2,88 mm) do que no grupo controle (-1,69 mm). **Conclusão:** No Grupo Controle, foi observada de forma notória a projeção dos incisivos inferiores nos arcos redondos, com projeção adicional causada pelos arcos retangulares. No Grupo Experimental, foi observada uma projeção mínima quando foram utilizados arcos redondos com CS acentuada para alinhamento. O nivelamento com arcos retangulares causou menos projeção com maior redução da CS.

Palavras-chave: Nivelamento e alinhamento. Projeção incisivo inferior. Tratamento ortodôntico sem extrações.

INTRODUCTION

Alignment and leveling is the first stage of comprehensive orthodontic treatment.[1] Typically, superelastic archwires, such as nickel-titanium (NiTi) alloys or multi-stranded stainless steel, are used in this stage due to alignment efficiency prior to inserting stiffer archwires.[2] Results of very effective dental changes early in treatment after alignment and leveling showed that proclination of mandibular incisors was common,[3] especially in non-extraction orthodontically-treated cases.[4-8] Proclination of mandibular incisors may affect the esthetic outcome, surrounding periodontal tissues,[9] and treatment stability.[10]

To correct crowded teeth, labial displacement of incisors is expected to gain spaces for tooth alignment.[5-8,11] To reduce this flaring, rectangular archwires, which have the ability of torque control, should be placed at the beginning stage.[12] Unfortunately, the placing of rectangular NiTi archwires with 0.016 x 0.022-in is probably not possible since the dimension of 0.022-in of the archwire cannot be forced into the disordered bracket slots on crowded teeth. Moreover, heavy forces could be expected from rectangular wire deflection.[13] In order to reduce this force with better torque control, 0.016 x 0.022-inch beta-titanium archwires with multiple loops can be introduced. However, complicated archwire bending, prolonged chair time, and the difficulty of oral hygiene practice must

be considered.[14] Therefore, a conventional sequence making use of the NiTi archwire for aligning is inevitable.

For tooth leveling or curve of Spee (COS) flattening, the placement of plain small round NiTi archwires can cause the incisors to flare up since intrusion forces are generated anterior to the centers of resistance of the incisors.[15] To counteract this flaring, a rectangular archwire can be applied for leveling after the crowded teeth are aligned.[16,17] The amount of incisor intrusion should be introduced little by little to avoid any heavy force.

Those problems led to the idea of changing the archwire shape to align the teeth with minimal leveling by using small round NiTi archwires with accentuated COS. Leveling can be subsequently approached using 0.016 x 0.022-in beta-titanium archwires with COS, then gradually flattened to generate optimal force.

The objective of the study was to investigate the movement of mandibular incisors focusing on the inclination when conventional round and rectangular archwires were used for aligning and leveling simultaneously, compared to accentuated COS archwires used for alignment followed by rectangular archwires for leveling.

MATERIAL AND METHODS

TRIAL DESIGN AND ANY CHANGES AFTER TRIAL COMMENCEMENT

This was a parallel-group prospective, randomized, controlled trial with a 1:1 allocation ratio. No changes were made to the methods during the trial.

PARTICIPANTS, ELIGIBILITY CRITERIA, AND SETTING

The trial was reviewed and approved by the Human Research Ethics Committee of the Faculty of Dentistry, Prince of Songkla University (Project No. EC6101-05-P-HR). The trial was reported according to the Consolidated Standards of Reporting Trials (CONSORT) statement[18] (Fig 1). Participants were recruited and treated in the orthodontic clinic of a university dental hospital. All subjects were informed of the study objectives and treatment protocol, and informed consent was received from the participants. The subjects were 18-30 years of age. The inclusion criteria included the following: (1) skeletal Class I (ANB angle = 1-5°); (2) all mandibular teeth were present, except third molars; (3) Little's irregularity index was in the range of 3-5 mm in which each contact was less than 1 mm; (4) the amount of posterior discrepancy was 0-2 mm; (5) COS depth was 3-4 mm; and (6) a non-extraction orthodontic treatment plan was indicated. The exclusion criteria were those individuals who had: (1) attached gingiva less than 1.5 mm, (2) clinical attachment loss more than 4 mm, (3) allergies, (4) systemic diseases, (5) drug use that altered bone metabolism, (6) previous orthodontic treatment, and (7) subjects who failed to attend monthly appointments.

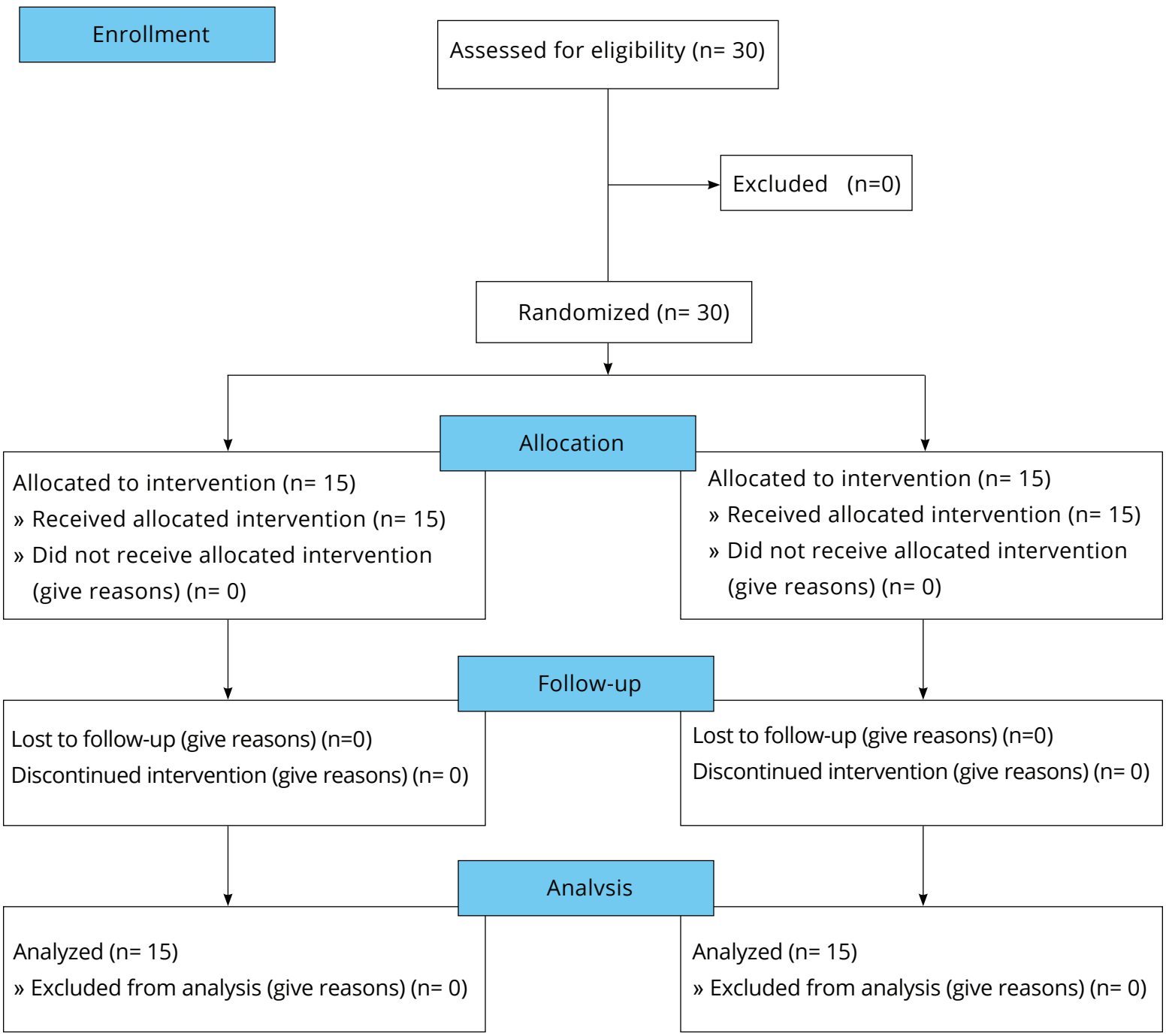


Figure 1: Modified CONSORT 2010 diagram.

INTERVENTIONS

Treatment began with bonding of the maxillary teeth until the mandibular teeth could be bonded using pre-adjusted Roth prescription edgewise brackets (0.018 x 0.025-in, Ormco Mini Diamond®, Orange, CA, USA).

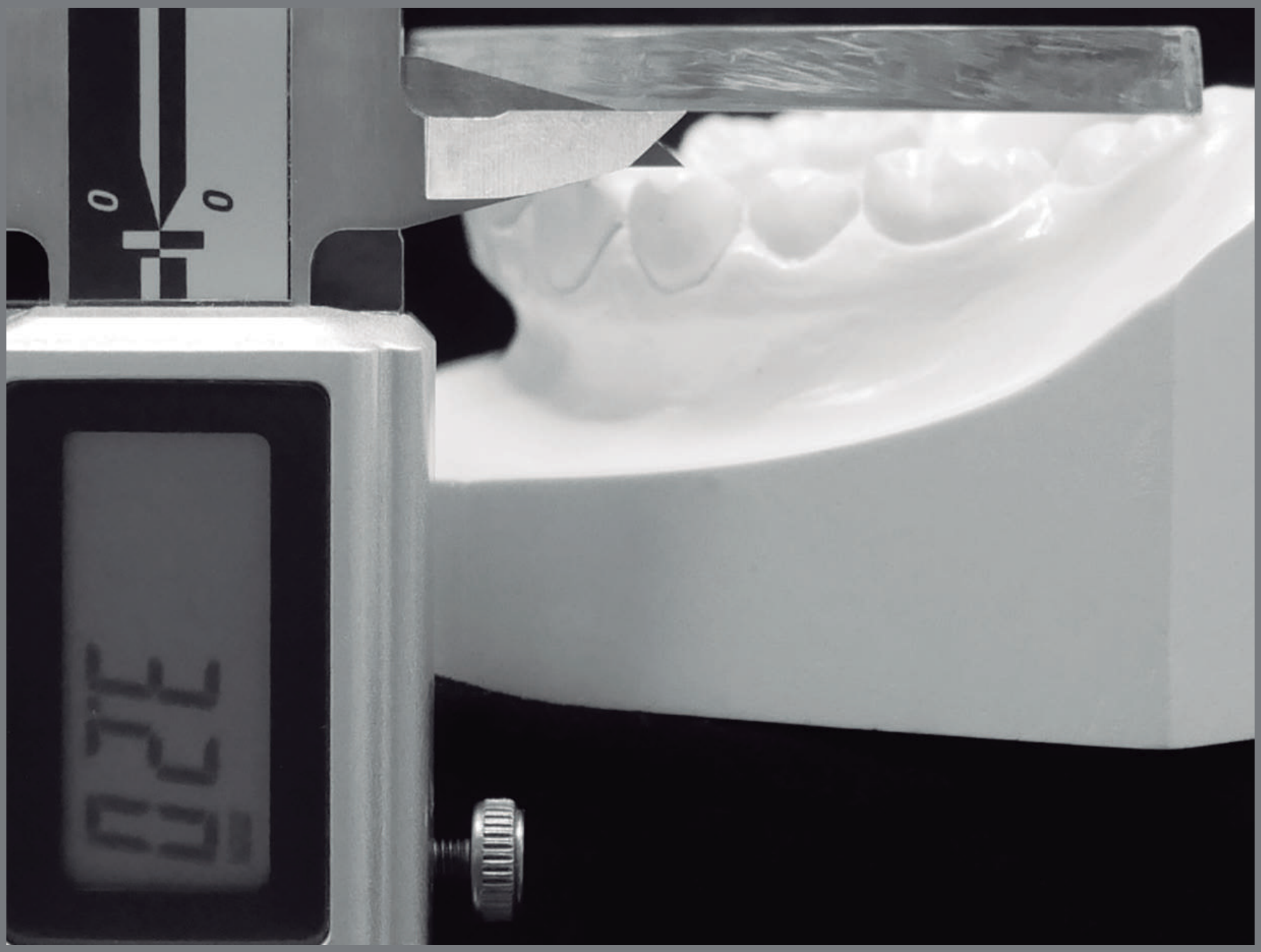


Figure 2: Curve of Spee depth measurement method.

The control group was treated with conventional alignment and leveling using 0.014-in and 0.016-in superelastic NiTi archwires (Great Lakes Orthodontics, NY, USA), 0.016 x 0.016-in, and 0.016 x 0.022-in stainless steel (Highland Metals, IN, USA). The experimental group was treated with 0.014-in and 0.016-in

superelastic NiTi archwires (Great Lakes Orthodontics, NY, USA) with a shallow reverse COS in an upside-down position (accentuated COS) to minimize altering the original COS during alignment. Then customized 0.016 x 0.016-in stainless steel with a passive COS and 0.016 x 0.022-in beta-titanium archwires (Highland Metals, IN, USA) gradually reduced the curve by 1.5 mm at each appointment until flat. This was followed by 0.016 x 0.022-in straight stainless steel. Appointments were at 3- to 4-week intervals.

Treatment records were obtained at three time points: (1) the initial data were recorded as T_0; (2) the data at the end of the alignment phase by 0.016-in superelastic NiTi archwires when Little's irregularity index was near zero and recorded as T_1; and (3) the data after three months of flat 0.016 x 0.022-in stainless steel archwires in place when the alignment and leveling phase was completed and recorded as T_2. The records taken at each time point were study models and lateral cephalometric radiographs.

STUDY MODEL AND CEPHALOMETRIC ANALYSES

Study models were evaluated using digital Vernier callipers set to zero before the next measurement for the amount of tooth crowding using Little's irregularity index.[19] The COS depth was assessed using a clear acrylic plate laid down from the mandibular second molars to the incisors measuring the average

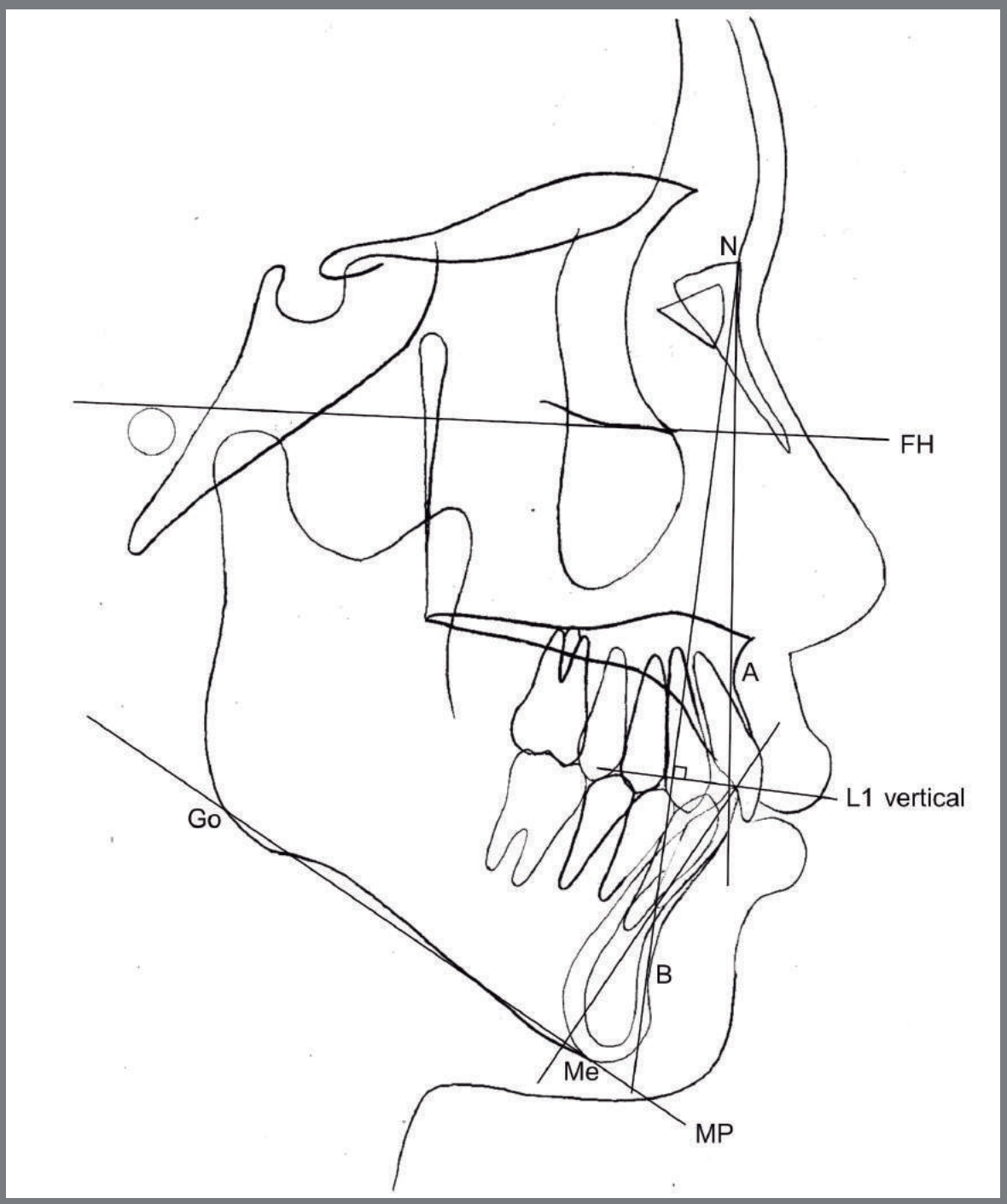


Figure 3: Lateral cephalometric measurements used in this study.

depth from the acrylic plate to the most inferior cusp tip of the bilateral premolars (Fig 2). The lateral cephalometric analysis evaluated position and inclination of the mandibular incisors and rotation of the mandibular plane (Fig 3).

SAMPLE SIZE CALCULATION

The sample size was calculated based on a previous study[20] with alpha = 0.01 for an independent *t*-test and a statistical power of 90%. The sample size required 13 subjects per group and two additional participants per group were included for possible drop-outs. Thus, the total number of participants in this study was 15 per group.

INTERIM ANALYSES AND STOPPING GUIDELINES

Not applicable.

RANDOMIZATION

Patients were divided into two parallel groups using simple randomization by drawing lots. Each participant was numbered for blinding by the first author. The lots were sealed in opaque envelopes for the group assignment. One resident member who was not part of the trial shuffled and opened the envelopes for each participant in a private room to ensure that the operator was blinded.

BLINDING

Blinding of the patients and operator was not possible; however, assessment was blinded and accomplished by an examiner not involved in patient treatment using lateral cephalometric radiographs and study models that were coded to conceal patient information.

STATISTICAL ANALYSIS

The data were analyzed using IBM SPSS Statistics 21 software (IBM Software Group, Chicago, IL, USA). Intra-examiner reliability was determined using paired *t*-tests by random selection of 10 cephalometric radiographs and 10 dental models after two weeks. The radiographs were retraced and measurements were repeated.

Means and standard deviations were calculated for all dental casts and lateral cephalometric radiograph parameters at T_0, T_1, and T_2. The distribution normality of parameters was tested by the Shapiro-Wilk test. Paired *t*-tests were used to analyse differences among T_0, T_1, and T_2 of the control and experimental groups. Independent *t*-tests were used to analyze differences between the control and experimental groups. A significant difference level of $p < 0.05$ was used for all statistical tests.

RESULTS

Thirty patients (11 males/19 females) with a mean age of 22.48 years were randomized in a 1:1 ratio into the control and experimental groups. No subjects were lost during the trial. The participant flow followed the modified CONSORT 2010 flow diagram (Fig 1). Thirty subjects were recruited into the trial between October 2017 and April 2018. The first initial records were taken in March 2018 and the final set in

January 2019. All 30 subjects were analyzed and none of the subjects missed any timepoints.

Intra-examiner reliability revealed no significant differences between repeated measurements ($p > 0.05$). Table 1 shows the demographic characteristics of the patients in each group. No differences in these factors between the two groups were noted, except the treatment time in the experimental group (35.13 weeks) was significantly longer than the control group (26.63 weeks) ($p < 0.0001$). Group differences of dental changes from the cephalometric analyses and model measurements at all timepoints are shown in Table 2.

In the control group, mandibular incisors were significantly aligned and leveled by round archwires and it was found that the mandibular incisors moved labially 1 mm and were significantly proclined 4.38° ($p < 0.0001$). In the vertical dimension, the mandibular incisors were intruded 1.13 mm ($p < 0.0001$) with COS reduction of 1.19 mm ($p < 0.0001$). After changing to rectangular archwires, the mandibular incisors intruded further by 0.63 mm ($p < 0.0001$) and proclined slightly 1.38° ($p < 0.0001$). Mandibular incisors moved very little lingually without statistical significance. The total COS reduction was 1.69 mm.

Table 1: Descriptive statistics for control and experimental groups.

Male:female ratio (%)	Total (n=30) 11:19 (36.67%:63.33%)		Control (n=15) 5:10 (33.33%:66.67%)		Experiment (n=15) 6:9 (40.00%:60.00%)		P-value
	mean	SD	mean	SD	mean	SD	
Age (years)	22.48	4.17	22.44	4.90	22.51	3.65	0.968
Overjet	2.85	0.68	3.07	0.62	2.63	0.69	0.083
Overbite	4.32	0.68	4.47	0.83	4.17	0.45	0.230
Irregularity index (mm)	3.75	0.74	3.91	0.74	3.59	0.73	0.235
ANB (degrees)	2.38	0.88	2.40	0.91	2.37	0.88	0.749
Curve of Spee (mm)	3.34	0.47	3.33	0.52	3.44	0.50	0.709
FMA (degrees)	25.88	3.52	24.75	2.93	27.00	3.88	0.284
Treatment time (weeks)	30.88	4.94	26.63	2.13	35.13	2.53	<0.0001*

*Significant difference between groups ($p<0.05$).

In the experimental group, tooth alignment was significantly performed by accentuated COS round archwires. The mandibular incisors moved 0.50 mm labially with 0.75° proclination without statistical significance. For mandibular incisors, no significant intrusion with no significant COS reduction was observed. When leveling by rectangular archwires, the mandibular incisors intruded by 1.75 mm ($p < 0.0001$) with 1.81° proclination ($p < 0.0001$) without significant labial movement (0.13 mm, $p = 0.170$). The COS was reduced by 2.69 mm ($p < 0.0001$).

Table 2: Dental changes from lateral cephalometric and model analysis.

Variables		Control (n=15)		Experiment (n=15)		P-value
		mean	SD	mean	SD	
L1 to NB (mm)	T_0	7.38	1.30	8.50	1.31	0.270
	T_1	8.38	1.30	9.00	1.31	0.652
	T_2	8.00	1.22	9.25	1.28	0.202
	T_1-T_0	1.00	0.00	0.50	0.00	0.655
	T_2-T_1	-0.38	0.23	0.13	0.23	<0.0001*
	T_2-T_0	0.63	0.23	0.63	0.23	0.215
L1 to NB (degrees)	T_0	27.38	4.41	33.00	2.00	0.020*
	T_1	31.75	4.12	33.75	2.17	0.419
	T_2	33.13	3.87	35.56	1.97	0.297
	T_1-T_0	4.38	0.44	0.75	0.38	<0.0001*
	T_2-T_1	1.38	0.44	1.81	0.80	0.408
	T_2-T_0	5.76	0.89	2.56	0.94	<0.0001*
FMA (degrees)	T_0	24.75	2.93	27.00	3.88	0.284
	T_1	25.00	2.84	27.25	3.78	0.271
	T_2	25.13	2.76	27.25	3.78	0.302
	T_1-T_0	0.25	0.42	0.25	0.38	0.709
	T_2-T_1	0.17	0.26	0.00	0.00	0.089
	T_2-T_0	0.42	0.49	0.25	0.38	0.486
Irregularity index (mm)	T_0	3.91	0.74	3.59	0.73	0.235
	T_1	0.21	0.10	0.27	0.15	0.166
	T_2	0.07	0.14	0.12	0.09	0.262
	T_1-T_0	-3.70	0.77	-3.31	0.71	0.161
	T_2-T_1	-0.11	0.17	-0.15	0.10	0.694
	T_2-T_0	-3.88	0.79	-3.68	0.74	0.155
Δ L1 vertical (mm)	T_1-T_0	-1.13	0.44	-0.38	0.23	<0.0001*
	T_2-T_1	-0.63	0.23	-1.75	0.38	<0.0001*
	T_2-T_0	-1.75	0.60	-2.13	0.35	0.569
Δ COS (mm)	T_1-T_0	-1.19	0.37	-0.19	0.37	0.709
	T_2-T_1	-0.50	0.00	-2.69	0.37	0.001*
	T_2-T_0	-1.69	0.37	-2.88	0.35	<0.0001*

*Significant difference within group and between groups ($p < 0.05$).

Crowding was almost completely resolved by 0.014-in and 0.016-in superelastic NiTi archwires in both control and experimental groups, and T_1 records were taken. At T_1, the irregularity indices in the control and experimental groups were significant reduced from 3.91 mm and 3.59 mm to 0.21 mm and 0.27 mm, respectively ($p = 0.166$). The mandibular incisors moved labially in the control and experimental groups by 1.00 mm and 0.50 mm, respectively ($p = 0.655$). The increase in proclination (0.75°) in the experimental group was significantly less than in the control group (4.38°) ($p < 0.0001$). At T_1, the amount of intrusion in the experimental group was -0.38 mm, which was significantly less than the control group (-1.13 mm) ($p < 0.0001$). COS reduction in the experimental group was -0.19 mm and -1.19 mm in the control group, no significant different was detected ($p = 0.709$).

After the placement of the flat 0.016 x 0.022-in stainless steel archwires, alignment and leveling were considered to be complete, and T_2 records were taken. At T_2, the mandibular incisors in the experimental group demonstrated labial movement of 0.63 mm, which was equal to the control group (0.63 mm) ($p = 0.215$). The increase in incisor proclination in the experimental group (2.56°) was significantly less than in the control group (5.76°) ($p < 0.0001$). The incisors had intruded in the experimental group (-2.13 mm) and the intrusion was significantly greater than the control group (-1.75 mm) ($p = 0.569$).

The total COS reduction in the experimental group was -2.88 mm and this was significantly greater than in the control group (-1.69 mm) ($p < 0.0001$). Neither group experienced changes in the Frankfort-mandibular plane angle greater than 0.5°. No serious harm such as gingival recession was observed in any of the subjects.

DISCUSSION

Mandibular incisor proclination is one of the undesirable side effects that occurs during the alignment and leveling stages of orthodontic treatment. Proclination can lead to periodontal damage, including gingival recession and alveolar bone loss.[21-25] To reduce this risk, a light rectangular beta-titanium archwire may be effective in maintaining better torque control[26] during the leveling stage. In this study, the experimental technique, which controlled the torque during leveling, was more effective in minimizing unwanted incisor flaring, compared to the conventional technique. The rectangular archwire could not be placed, unless accentuated COS round archwire was innovated for aligning without leveling. The final result was significant COS reduction with less proclination. Totally, the COS was reduced by 2.88 mm with 2.56° flaring or 0.89° per mm. In the control group, the COS was reduced by 1.19 mm with 4.38° flaring while using the round archwires and more proclination (1.38°) occurred with a COS reduction of 0.50 mm while using the rectangular archwires. Totally, the

COS was reduced by 1.69 mm with 5.76° flaring or 3.44° per mm. Comparing the ratios of COS reduction and proclination within 1 mm intrusion, the separation technique caused less proclination (0.89°) than the conventional procedure.

During alignment with round superelastic archwires, the straight round NiTi archwires in the control group contributed to increased mandibular incisor proclination during alignment and leveling because they applied an intrusive force on the incisors that was facial to the center of resistance.[15] As a result, the incisors in the control group exhibited the most intrusion and flaring at T_1. After placing the rectangular archwires, the mandibular incisors continued to procline with some more intrusion. This could imply that after the extreme proclination caused by the round archwire, lingual crown torque, by subsequently placing the rectangular archwire, could not be expected. Moreover, the remaining COS still allowed the intrusion force from the rectangular wire to create more proclination. The rectangular archwires could not reduce the proclination caused from the round archwires because the moment of couple in the bracket slots for torqueing the incisors was much smaller than the moment of intrusive force.

NiTi archwires with preformed accentuated COS matching to an individual's COS may be an appropriate alternative to achieve alignment in cases where proclination of the mandibular incisors is undesirable or in cases in which a flat COS is not a treatment goal. To achieve leveling in the experimental group, a rectangular beta-titanium archwire was used to gradually reduce the COS while maintaining torque control. Unfortunately, the treatment time in the torque-controlled method was 8.5 weeks longer, which was mainly due to the rectangular archwire stage when the archwire was passively placed followed by gradual reduction of the COS. Incidentally, this technique found significantly less mandibular incisor proclination (control: 5.76°; experimental: 2.56°) with more mandibular incisor intrusion (control: -1.75 mm; experimental: -2.13 mm). Since the amount of intrusion was limited from the gradual COS reduction, the amount of moment of intrusive force would decrease. This allowed the moment of couple in the bracket's slot to express lingual crown torque. However, the incisors were still proclined, but less than the control group. Thus, this technique could control the mandibular incisor inclination and be beneficial for patients who need deep COS correction whenever incisor proclination is limited.

A comparison between the two groups in the reduction of COS from mandibular incisor intrusion revealed that the control group had the most substantial proclination during the round wire phase (T_1-T_0). However, in the experimental group, reduction of the COS occurred mostly during the rectangular wire phase with less proclination. This could imply that the small round archwires could be the archwire of choice for leveling when proclination is allowed.

A previous study by Pandis et al[27] also reported that proclination of mandibular incisors was the main result of a flattened COS. Their study exhibited a large amount of mandibular incisor proclination (4.70°) after 1 mm leveling of the COS. This was comparable to the control group in this study in the round wire phase (4.38°) that occurred during the T_1-T_0 interval of approximately 1 mm mandibular incisor intrusion and COS correction. In the experimental group of this study, less mandibular incisor proclination was found and was attributed to the torque effect of the rectangular archwires. Additionally, AlQabandi et al[28] leveled mandibular teeth with rectangular archwires; however, they used NiTi archwires, which were not stiff and could not express the required torque. Therefore, the mandibular incisors were still proclined, as observed in the round archwire group. Meling and Odegaard[26] found that rectangular beta-titanium archwires were 1.6 times stiffer than NiTi archwire. As a result, rectangular beta-titanium archwires

may be more suitable for reducing a deepened COS due to their torque effectiveness and the ability to produce the light forces recommended for mandibular incisor intrusion.[12]

This study was a prospective randomized clinical trial that investigated a two-part technique by first incisor aligning and then flattening the COS by controlled mandibular incisor torque, compared to conventional treatment methods. The results from this finding demonstrate two movements, first by round archwires and subsequently, by rectangular archwires. Other studies[5-8,27,29] reported the results from total treatment with durations of more than a year and included the finishing phase, which may affect the mandibular incisor position from wire bending, torqueing or intermaxillary elastics.

Proclination is a major concern in this study due to possible risks[9,10]. The control group presented statistically significant greater incisor proclination (3.20°) compared to the experimental group. This amount of proclination difference may not be considered to be clinically significant. An additional study of surrounding bone response to these changes would be interesting to confirm whether this amount of proclination is safe for the periodontium. The results of this study can be applied only in non-extraction patients who have similar pre-treatment characteristics of crowding in the mandibular anterior teeth of 3-5 mm and 3-4 mm COS.

CONCLUSIONS

In the control group, mandibular incisor proclination was markedly observed in round archwires, with further proclination caused by rectangular archwires. In experimental group, minimal proclination was exhibited when accentuated COS round archwires were used for aligning. Leveling with rectangular archwires caused less proclination with more COS reduction.

AUTHORS' CONTRIBUTION

Pornpat Theerasopon (PT)

Steven J. Lindauer (SJL)

Chairat Charoemratrote (CC)

Conception or design of the study:

CC

Data acquisition, analysis or interpretation:

PT, SJL, CC.

Writing the article:

PT, CC.

Critical revision of the article:

PT, SJL, CC.

Final approval of the article:

PT, SJL, CC.

Fundraising:

CC.

Overall responsibility:

CC.

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

REFERENCES

1. Proffit WR, Fields HW, Sarver DM. Contemporary Orthodontics. St. Louis, Mo: Elsevier/Mosby; 2013.

2. Abdelrahman R, Al-Nimri KS, Al Maaitah EF. A clinical comparison of three aligning archwires in terms of alignment efficiency: A prospective clinical trial. Angle Orthod. 2015;85(3):434-9.

3. Baratieri C, Rocha R, Campos C, Menezes L, Ribeiro GLU, Ritter D, et al. Evaluation of the lower incisor inclination during alignment and leveling using superelastic NiTi archwires: a laboratory study. Dental Press J Orthod. 2012;17:51-7.

4. Park HK, Sung EH, Cho YS, Mo SS, Chun YS, Lee KJ. 3-D FEA on the intrusion of mandibular anterior segment using orthodontic miniscrews. Korean J Orthod. 2011;41(6):384-98.

5. Bishara SE, Cummins DM, Zaher AR. Treatment and posttreatment changes in patients with Class II, Division 1 malocclusion after extraction and nonextraction treatment. Am J Orthod Dentofacial Orthop. 1997;111(1):18-27.

6. Basciftci FA, Usumez S. Effects of extraction and nonextraction treatment on Class I and Class II subjects. Angle Orthod. 2003;73(1):36-42.

7. Pandis N, Polychronopoulou A, Eliades T. Self-ligating vs conventional brackets in the treatment of mandibular crowding: A prospective clinical trial of treatment duration and dental effects. Am J Orthod Dentofacial Orthop. 2007;132(2):208-15.

8. Yitschaky O, Neuhof MS, Yitschaky M, Zini A. Relationship between dental crowding and mandibular incisor proclination during orthodontic treatment without extraction of permanent mandibular teeth. Angle Orthod. 2016;86(5):727-33.

9. Choi YJ, Chung CJ, Kim KH. Periodontal consequences of mandibular incisor proclination during presurgical orthodontic treatment in Class III malocclusion patients. Angle Orthod. 2015;85(3):427-33.

10. Schulhof RJ, Allen RW, Walters RD, Dreskin M. The mandibular dental arch: Part I, lower incisor position. Angle Orthod. 1977;47(4):280-7.

11. Germane N, Lindauer SJ, Rubenstein LK, Revere JH, Isaacson RJ. Increase in arch perimeter due to orthodontic expansion. Am J Orthod Dentofacial Orthop. 1991;100(5):421-7.

12. Gurgel JA, Pinzan-Vercelino CRM, Powers JM. Mechanical properties of beta-titanium wires. Angle Orthod. 2011;81(3):478-83.

13. Parvizi F, Rock WP. The load/deflection characteristics of thermally activated orthodontic archwires. Eur J Orthod. 2003;25(4):417-21.

14. Chambers C, Stewart S, Su B, Sandy J, Ireland A. Prevention and treatment of demineralisation during fixed appliance therapy: a review of current methods and future applications. Br Dent J. 2013;215(10):505-11.

15. Theerasopon P, Kosuwan W, Charoemratrote C. Stress assessment of mandibular incisor intrusion during initial leveling in continuous arch system with different archwire shapes of superelastic nickel-titanium: A three-dimensional finite element study. Int J Health Allied Sci. 2019;8(2):92-7.

16. Archambault A, Major TW, Carey JP, Heo G, Badawi H, Major PW. A comparison of torque expression between stainless steel, titanium molybdenum alloy, and copper nickel titanium wires in metallic self-ligating brackets. Angle Orthod. 2010;80(5):884-9.

17. Martins RP. Early vertical correction of the deep curve of Spee. Dental Press J Orthod. 2017;22:118-25.

18. Moher D, Hopewell S, Schulz KF, Montori V, Gotzsche PC, Devereaux PJ, et al. CONSORT 2010 Explanation and Elaboration: Updated guidelines for reporting parallel group randomised trials. J Clin Epidemiol. 2010;63(8):e1-37.

19. Little RM. The irregularity index: a quantitative score of mandibular anterior alignment. Am J Orthod. 1975;68(5):554-63.

20. Tantikalyaporn C. The effects of lower incisor intrusion in Class II growing patients. Songkhla, Thailand: Prince of Songkla University; 2014.

21. Steiner GG, Pearson JK, Ainamo J. Changes of the marginal periodontium as a result of labial tooth movement in monkeys. J Periodontol. 1981;52(6):314-20.

22. Engelking G, Zachrisson BU. Effects of incisor repositioning on monkey periodontium after expansion through the cortical plate. Am J Orthod. 1982;82(1):23-32.

23. Årtun J, Krogstad O. Periodontal status of mandibular incisors following excessive proclination: A study in adults with surgically treated mandibular prognathism. Am J Orthod Dentofacial Orthop. 1987;91(3):225-32.

24. Garlock DT, Buschang PH, Araujo EA, Behrents RG, Kim KB. Evaluation of marginal alveolar bone in the anterior mandible with pretreatment and posttreatment computed tomography in nonextraction patients. Am J Orthod Dentofacial Orthop. 2016;149(2):192-201.

25. Theerasopon P, Charoemratrote C. Periodontal tissues after level and align lower anterior teeth in non-extraction orthodontic treatment. J Dent Assoc Thai. 2019;69(3):260-70.

26. Meling TR, Odegaard J. On the variability of cross-sectional dimensions and torsional properties of rectangular nickel-titanium arch wires. Am J Orthod Dentofacial Orthop. 1998;113(5):546-57.

27. Pandis N, Polychronopoulou A, Sifakakis I, Makou M, Eliades T. Effects of levelling of the curve of Spee on the proclination of mandibular incisors and expansion of dental arches: a prospective clinical trial. Aust Orthod J. 2010;26(1):61-5.

28. AlQabandi AK, Sadowsky C, BeGole EA. A comparison of the effects of rectangular and round arch wires in leveling the curve of Spee. Am J Orthod Dentofacial Orthop. 1999;116(5):522-9.

29. Erdinc AE, Nanda RS, Isiksal E. Relapse of anterior crowding in patients treated with extraction and nonextraction of premolars. Am J Orthod Dentofacial Orthop. 2006;129(6):775-84.

Dental Press Journal of ORTHODONTICS

Volume 26 - Number 2 - Online

ORIGINAL ARTICLE

https://doi.org/10.1590/2177-6709.26.2.e212020.oar

Effect of fluoride on mechanical properties of NiTi and CuNiTi orthodontic archwires: an *in vitro* study

Pratap **MANE**[1] ✉

https://orcid.org/0000-0002-1090-8202

Chanamallappa R. **GANIGER**[1]

https://orcid.org/0000-0002-0118-8178

Renuka **PAWAR**[1]

https://orcid.org/0000-0002-6417-6799

Sandesh **PHAPHE**[1]

https://orcid.org/0000-0002-0412-804X

Yusuf Ahammed **RONAD**[1]

https://orcid.org/0000-0003-3318-745X

Seema **VALEKAR**[1]

https://orcid.org/0000-0002-0437-0581

Aditi Aneesh **KANITKAR**[2]

https://orcid.org/0000-0002-6661-0931

Submitted: March 12, 2020 • **Revised and accepted:** March 29, 2020

✉ drpratapmane31@gmail.com

How to cite: Mane P, Ganiger CR, Pawar R, Phaphe S, Ronad YA, Valekar S, Kanitkar AA. Effect of fluoride on mechanical properties of NiTi and CuNiTi orthodontic archwires: an in vitro study. Dental Press J Orthod. 2021;26(2):e212020.

(1) Krishna Institute of Medical Sciences, School of Dental Sciences, Department of Orthodontics and Dentofacial Orthopedics (Malkapur, Karad/MH, India). (2) Bharati Vidyapeeth Dental College & Hospital, Department of Prosthodontics (Sangli/MH, India).

ABSTRACT

Introduction: After debonding, white spot may appear on the area below the bracket, which is the early clinical sign of carious lesion. There is increased caries risk underneath and adjacent to orthodontic bands and brackets, which call for maximum use of caries preventive procedures using various fluoride application methods.

Objective: The aim of the study was to evaluate alterations in the mechanical properties (modulus of elasticity and yield strength) in loading and unloading phases for different orthodontic archwires (nickel-titanium [NiTi] and copper-nickel-titanium [CuNiTi]) when exposed routinely to fluoride prophylactic agents for a predetermined period of time.

Methods: Preformed rectangular NiTi and CuNiTi wires were immersed in fluoride solution and artificial saliva (control) for 90 minutes at 37°C. After immersion, specimens were tested using a 3-point bend test on a universal testing machine.

Results: There is a significant reduction in the unloading yield strength when the NiTi and CuNiTi wires were exposed to APF gel.

Conclusion: The result suggests that use of topical fluoride agents affect the mechanical properties of the wires, leading to increase in treatment duration. Fluoride prophylactic agents must be used with caution in patients undergoing orthodontic treatment. Injudicious use of these agents may cause corrosive effects on the orthodontic wire surfaces, with alteration in their mechanical properties.

Keywords: NiTi. CuNiTi. Fluoride. Orthodontic wires. Instron machine.

RESUMO

Introdução: Após a remoção dos braquetes, manchas brancas podem aparecer na área embaixo deles, as quais são o sinal clínico inicial da lesão cariosa. Existe um maior risco de cáries embaixo e ao redor das bandas e braquetes ortodônticos, o que exige a máxima utilização de procedimentos preventivos de cárie, usando diferentes métodos com aplicação de flúor.

Objetivo: O objetivo do presente estudo foi avaliar alterações nas propriedades mecânicas (módulo de elasticidade e resistência ao escoamento), nas fases de carregamento e descarregamento de diferentes fios ortodônticos (níquel-titânio [NiTi] e níquel-titânio com adição de cobre [CuNiTi]), quando expostos rotineiramente a agentes profiláticos fluoretados, utilizados durante um período de tempo predeterminado.

Métodos: Os fios pré-contornados retangulares de NiTi e CuNiTi foram imersos em solução fluoretada e saliva artificial (controle) durante 90 minutos a 37°C. Após a imersão, as amostras foram testadas utilizando-se um teste de flexão em três pontos, em uma máquina universal de testes.

Resultados: Houve uma redução significativa na resistência ao escoamento na fase de descarregamento quando os fios de NiTi e CuNiTi foram expostos ao gel fluoretado.

Conclusão: O resultado sugere que o uso tópico de agentes fluoretados afeta as propriedades mecânicas dos fios, levando a um aumento na duração do tratamento. Os agentes profiláticos fluoretados devem ser utilizados com cautela em pacientes submetidos a tratamento ortodôntico. O uso indiscriminado desses agentes pode causar efeitos corrosivos na superfície dos fios ortodônticos e consequente alteração das suas propriedades mecânicas.

Palavras-chave: NiTi. CuNiTi. Fluoreto. Fios ortodônticos. Máquina Instron.

INTRODUCTION

After debonding, white spot may appear on the area below the bracket, which is the early clinical sign of carious lesion. There is increased caries risk underneath and adjacent to orthodontic bands and brackets, which call for caries preventive procedures using fluoride application methods.

Orthodontic tooth movement results from forces produced by the appliances (wires, brackets, elastics, etc) inserted and activated by the clinician.[1]

NiTi wires are predominantly used in the early stage of orthodontic treatment.

Orthodontists routinely move teeth by attaching brackets to them and activating archwires within the slots of brackets. During space closure, sliding a wire through the slot of a bracket may produce frictional forces, which opposes the treatment plan.

Slot size, surface characteristics of bracket/archwire and the forces used produce friction during orthodontic tooth movement. According to Watanabe et al,[4] in 2003, the surface roughness of titanium-based archwires increases after exposure to fluoride containing prophylactic agents. Change in the surface characteristics of archwire compromises the sliding of brackets along the archwires.

In 2005, Walker et al[2] showed that NiTi-based archwires upon exposure to neutral and acidulated fluoride prophylactic agents decreased in mechanical properties.

Wires containing nickel are used routinely during orthodontic treatment. Oxygen reacts with the surface of all metals to form anoxide surface layer, which protects the metallic surface from corrosion. When friction occurs between the archwires and brackets, the oxide layer dissolves and surface corrosion and pitting take place.

The current study aimed to evaluate changes in the mechanical properties (modulus of elasticity and yield strength), during loading and unloading phases for different orthodontic archwires, when exposed to routinely used fluoride prophylactic agent for a predetermined period of time. Considering the beneficial effects of the prophylactic agents in preventing decalcification of teeth around orthodontic brackets, the objective of this study is to determine whether exposure to these fluoride prophylactic agents causes pitting and corrosion on the surfaces of archwires.

MATERIAL AND METHODS

The materials used for the study included:

1. NiTi and CuNiTi preformed archwires.
2. Phos-Flur gel and PreviDent 5000
3. Deionized water

The two groups of wires (30 wire specimens) selected were:

» Group I: 0.017 x 0.025-in NiTi archwires (Libral, Okhla Industrial Area, New Delhi, India).
» Group II: 0.017 x 0.025-in CuNiTi archwires (Libral, Okhla Industrial Area, New Delhi, India).

The fluoride agents selected were as follows:

1. Phos-Flur gel (1.1% sodium fluoride acidulated phosphate APF, 0.5% w/v fluoride pH=5.1; Colgate oral pharmaceuticals, New York, USA).
2. PreviDent 5000 (1.1% sodium fluoride neutral agents 0.5% w/v fluoride pH=7; Colgate oral pharmaceuticals, New York, USA).

These fluoride agents were chosen because of their identical methods of application, identical fluoride ion concentrations and differences in pH.

Figure 1: A) Phos-Flur gel, deionized water and PreviDent gel. **B)** Wires used.

The control solution used was deionized water [dH_2O].

Each wire specimen was 0.42 X 0.62 X 25mm in dimension, cut from the straight portion of the preformed archwires.

METHODS

The control group and experimental groups were established.

Control group:

» Ten (n = 10) wire samples consisting of five (n = 5) samples from each wire group, placed in deionized water.

Experimental groups:

» Group I: Ten (n = 10) wire samples consisting of five (n = 5) samples from each wire group, placed in the Phos-Flur gel.
» Group II: Ten (n = 10) wire samples consisting of five (n = 5) samples from each wire group, placed in PreviDent 5000.

Five wires from each group were incubated in 2ml of deionized water at 37°C in an individual plastic 10ml vial or container. This constituted the control sample, with a total of 10 samples.

Five wires from each group were incubated in 2ml of each fluoride-containing agents in individual plastic containers at 37°C for 90 minutes. These wires constituted the two experimental groups.

Walker et al,[2] in 2005, stated that three months of 1 minute daily topical fluoride application or fluoride rinse is equivalent to exposure time of 90 minutes.

Prior to the mechanical testing, the experimental group wires were washed-off with deionized water after removing from the respective solutions and placed in clean and individually coded containers. Wires were randomly selected and were tested using a 3-point bend test on a universal testing machine (model no. 5582J5146, INSTRON; Canton, Mass. USA).

The wires were tested in a chamber with the temperature 37 ± 1°C, which is similar to the oral environment. Each wire was loaded to a deflection of 3.1mm and then unloaded to zero deflection at a cross-head speed of 1mm/min.

Using the Merlin software program (version 5.43), load in Newtons (N) and deflection in mm were collected every 100 milliseconds for both loading and unloading, for each wire. Using engineering beam theory, Modulus of elasticity (E) and yield strength (YS) in both loading and unloading were calculated using the following formula:

$E = L^3m/4bd^3$ (GPA)

L = Support span (mm)

b = Width of specimen (mm)

d = Depth of specimen (mm)

m = slope of the straight line position of the loaded or unloaded – deflection curve (N/mm of deflection)

The yield strength (YS) was also calculated as follows:

$YS = 3\ PL\ /2\ bd^2$ (mPa)

P = Load at the apparent yield point (N)

L = support span (mm)

b = width of specimen (mm)

d = depth of specimen (mm)

ANOVA test was used to do the statistical analysis.

RESULTS

The distribution of average values for the loading and unloading properties of NiTi wire specimens in deionized water (control) and other experimental fluoride agents is presented in Table 1 and Figure 2A.

Table 1: The distribution of average values for the loading and unloading properties of NiTi wire specimens in deionized water (control) and other experimental fluoride agents.

Wire type	Solution	Mean (SD)			
		Loading yield strength (Mpa)	Loading elastic modulus (Gpa)	Unloading yield strength (Mpa)	Unloading elastic modulus (Gpa)
NiTi (n=30)	Deionized water (control) (n=10)	625.5 (38.8)	484.6 (19.7)	334.1 (23.3)	448.6 (2.6)
	Phos-Flur (n=10)	582.7 (61.3)	455.6 (41.4)	258.4 (43.9)	408.2 (45.0)
	PreviDent (n=10)	597.5 (43.2)	454.2 (24.4)	312.8 (33.8)	430.6 (23.2)
	Total (All agents) (n=30)	601.9 (50.4)	464.8 (32.2)	301.8 (46.6)	429.1 (32.8)

Values are presented as mean (SD).

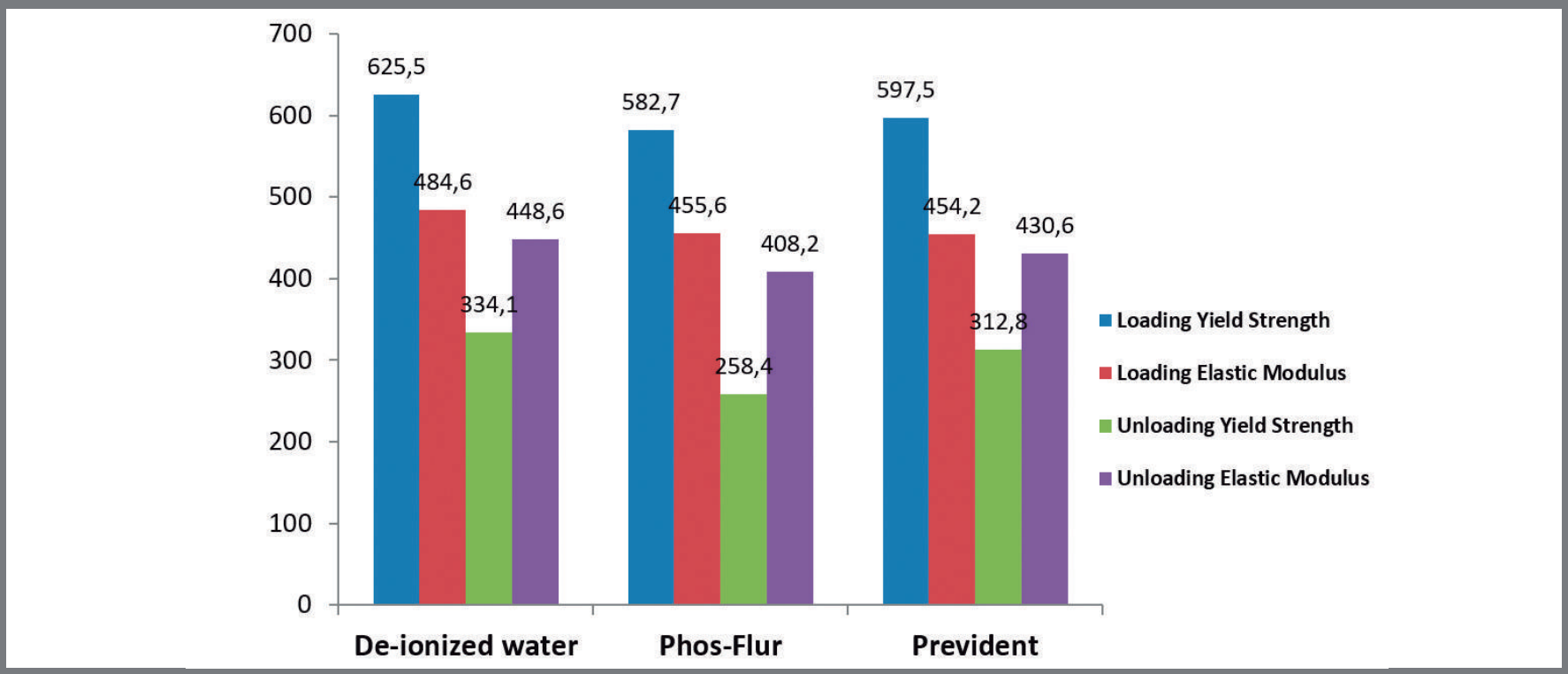


Figure 2A: The distribution of average values for the loading and unloading properties of NiTi wire specimens in deionized water (control) and other experimental fluoride agents.

Statistical comments:

a) In loading properties, Average yield strength and elastic modulus was not significantly different between various experimental fluoride agents.

b) In unloading properties, Average yield strength and elastic modulus was significantly higher in deionized water, compared to Phos-Flur, but there was no significant difference between deionized water and PreviDent. However, Average yield strength was significantly higher in PreviDent compared to Phos-Flur but the elastic modulus showed no significant difference between Phos-Flur and PreviDent.

The distribution of average values for the loading and unloading properties of CuNiTi wire specimens in deionized water (control) and other experimental fluoride agents is presented in Table 2 and Figure 2B.

Table 2: The distribution of average values for the loading and unloading properties of CuNiTi wire specimens in deionized water (control) and other experimental fluoride agents.

Wire type	Solution	Mean (SD)			
		Loading yield strength (Mpa)	Loading elastic modulus (Gpa)	Unloading yield strength (Mpa)	Unloading elastic Modulus (Gpa)
CuNiti (n=30)	Deionized water (control) (n=10)	363.8 (18.1)	369.9 (35.9)	336.9 (7.9)	165.5 (4.7)
	Phos-Flur (n=10)	325.9 (35.4)	325.1 (57.8)	309.5 (35.4)	164.1 (6.9)
	PreviDent (n=10)	357.2 (7.9)	335.8 (24.8)	334.1 (13.6)	165.6 (6.7)
	Total (All agents) (n=30)	348.9 (28.2)	343.6 (44.8)	326.9 (24.9)	165.1 (6.0)

Values are presented as Mean (SD).

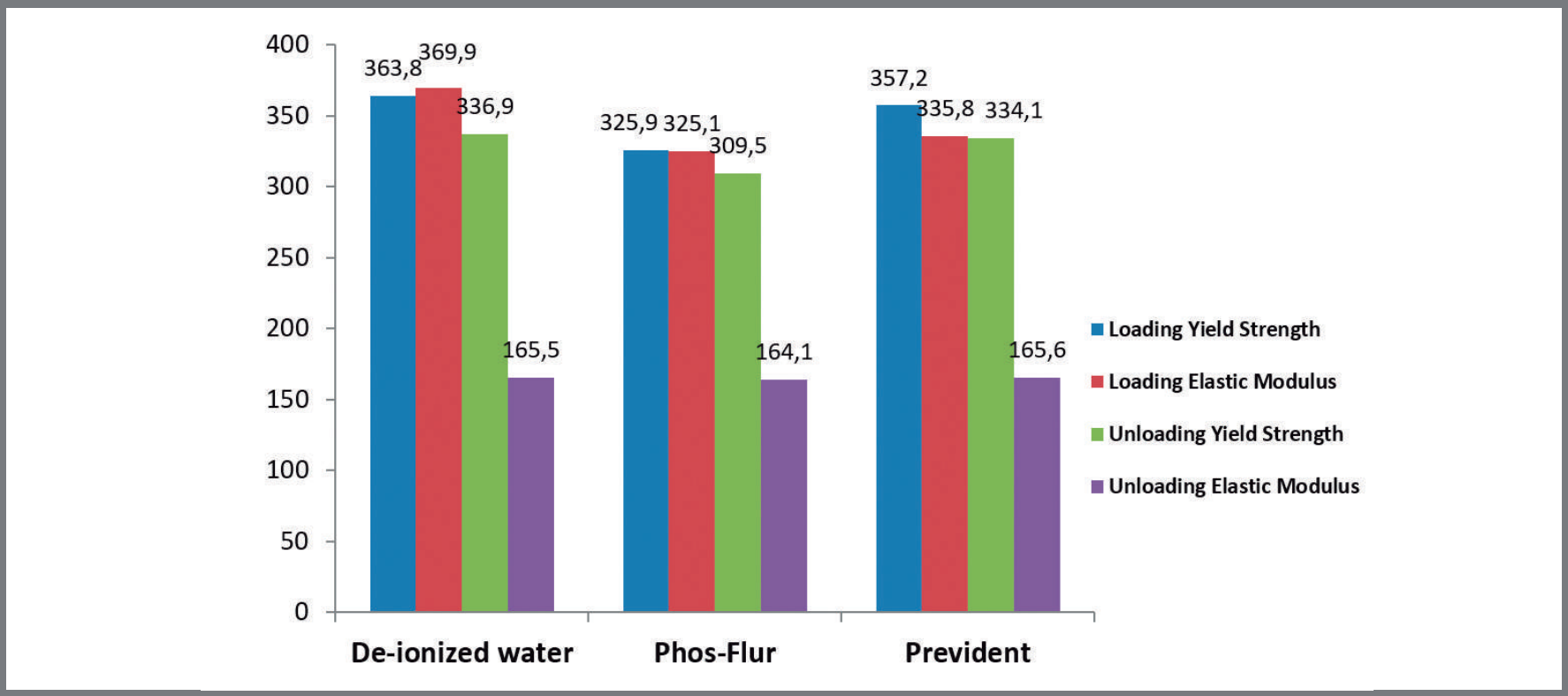


Figure 2B: The distribution of average values for the loading and unloading properties of CuNiTi wire specimens in deionized water (control) and other experimental fluoride agents.

Statistical comments:

a) In loading properties, Average yield strength was significantly higher in deionized water compared to Phos-Flur, and also it was higher in PreviDent compared to Phos-Flur.

b) Average yield strength was not significantly different between deionized water and PreviDent. The Average elastic modulus was not significantly different between various experimental fluoride agents.

c) In unloading properties, Average yield strength was significantly higher in deionized water compared to Phos-Flur, and it was significantly higher in PreviDent compared to Phos-Flur.

d) The average yield strength was not significantly different between deionized water and PreviDent. The Average elastic modulus was not significantly different between various experimental fluoride agents.

Clinically, corrosion of the CuNiTi wire surfaces increases the friction at the bracket/wire interface, which affects the tooth movement.

DISCUSSION

In this study, evaluation of two types of wires was done to observe the effect of fluoride agents on unloading mechanical properties (yield strength and modulus of elasticity).

Corrosion of titanium-based archwires[2-9] has been reported due to application of topical fluorides, which suggests that mechanical properties of titanium-based alloys may be altered due to fluoride application, mainly because of hydrogen embrittlement. This further may reduce the clinical efficiency, by increasing the resistance during tooth movement, which can lead to anchorage loss during leveling and aligning, and also during retraction phase.

According to Toumelin-Chamela et al,[5] due to hydrogen embrittlement, there is an increase in fracture susceptibility of titanium-based orthodontic wire when kept in fluoride solution. There is a decrease in alloy's mechanical properties[12,13] due to formation of titanium hydrides, which is reported to form a body centered tetragonal structure[11].

Sodium fluorides and hydrogen fluoride can cause rapid corrosion[14]. On exposure of titanium-based orthodontic wires to acidulated and neutral topical fluoride agents, hydrofluoric acid (HF) is produced, according to the following equation:

$$H_3PO_4 + 3\ NAF \rightarrow NA_3PO_4 + 3\ HF$$

The protective oxide layer on the surface is dissolved by hydrofluoric acid causing corrosion and absorption of hydrogen ions from the fluoride solutions, due to high affinity of titanium with hydrogen,[15] according to the following equation:

$$TI_2O_3 + 6\ HF \rightarrow 2TIF_3 + 3H_2O$$

$$TIO_2 + 4\ HF \rightarrow TIF_4 + 2H_2O$$

$$TIO_2 + 2\ HF \rightarrow TIF_2 + H_2O$$

When the fluoride exposure increases, the tensile strength of NiTi alloy decreases to the critical stress level of martensite transformation. Therefore, evaluation of mechanical properties of wire along with corrosion is relevant caused by fluoride agents.

When the NiTi wires were exposed to fluoride for 90 minutes, a decrease in both unloading modulus of elasticity and the unloading yield strength of the wire was found. This is due to the formation of titanium hydride, caused by the hydrogen penetration in the lattice of the NiTi, which alters the lattice's

ability to undergo the unloading phase shift from the martensite form to the austenitic form. In a clinical setting, exposure of NiTi wires to fluoride causes reduction of the tooth movement during unloading stage and also affects the spring-back property of these wires. The effects of fluoride on wire also depends upon the pH and fluoride content of the agent.

When NiTi wires were exposed to APF gel, there was a significant decrease in unloading yield strength, but the unloading modulus of elasticity did not significantly decrease. The mechanical properties are more affected, compared to fluoride agents.

When CuNiTi wires were exposed to APF gel there was a significant decrease in unloading yield strength, compared to control samples.

Due to the presence of copper in CuNiTi wires at the alloy/oxide interface, which avoids the hydrogen penetration, that will reduce the formation of titanium hydride in the lattice structure.

In this study, there was significantly higher yield strength in control PreviDent gel, compared to acidulated Phos-Flur gel; and during the unloading phase, the CuNiTi wires showed significant decrease in mechanical properties. Also, in the present study only the unloading phase was studied, therefore there is a scope for the study of effects of fluoride agents on the mechanical properties.

CONCLUSION

In the present study, NiTi wires upon exposure to fluoride agents showed significant decrease in mechanical properties. Clinically it is the deactivation forces that cause depletion of mechanical properties of titanium-based archwires. Decrease in the unloading yield strength produces adverse effect, due to the spring-back property of these wires.

Previous studies have shown that 90 minutes is equivalent to one minute daily application/rinses for a period of approximately three months.[1] Therefore, in this study the NiTi wires that usually remain in oral environment for more amount of time during leveling and aligning purpose were tested. The fluoride agents that were used are the commonly prescribed oral hygiene agents.

In conclusion, this study suggests that the routinely used fluoride prophylactic agents should be cautiously used in patients during orthodontic treatment because the excess and prolonged use of these agents may cause corrosion of orthodontic wire surfaces along with alteration in mechanical properties, leading to prolonged treatment time.

AUTHORS' CONTRIBUTION

Pratap Mane (PM)

Chanamallappa R. Ganiger (CRG)

Renuka Pawar (RP)

Sandesh Phaphe (SP)

Yusuf Ahammed Ronad (YAR)

Seema Valekar (SV)

Aditi Aneesh Kanitkar (AAK)

Conception or design of the study:

PM

Data acquisition, analysis or interpretation:

PM, CRG, RP, SP, YAR, SV, AAK.

Writing the article:

RP.

Critical revision of the article:

PM, CRG, RP, SP, YAR, SV, AAK.

Final approval of the article:

PM, CRG, RP, SP, YAR, SV, AAK.

Overall responsibility:

SV, AAK.

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

REFERENCES

1. Ravindra N. Biomechanics in clinical orthodontics. Philadelphia: W.B. Saunders Company;1996

2. Walker MP, White RJ, Kula KS. Effect of fluoride prophylactic agents on the mechanical properties of nickel-titanium based orthodontic wires. Am J Orthod Dentofacial Orthop. 2005;127(6);662-9.

3. Nakagawa M, Matsuya S, Shirashi T, Ohta M. The effect of fluoride concentration & pH on corrosion behaviour of titanium for dental use. J Dent Res. 1999;78(9):1568-72.

4. Watanabe I, Watanabe E. Surface changes induced by fluoride prophylactic agents on titanium based orthodontic wires. Am J Orthod Dentofacial Orthop. 2003;123(6):653-6.

5. Toumelin-Chamela F, Rouelle F, Burdairon G. Corrosive properties of fluoride containing odontologic gels against titanium. J Dent. 1996; 24(1):109-15.

6. Kaneko K, Yokoyama K, Moriyama K, Asaoka K, Sakai J. Degradation in performance of orthodontic wires caused by hydrogen absorption during short immersion in 2.0% acidulated phosphate fluoride solution. Angle Orthod. 2004;74(4):489-95.

7. Huang HH. Effects of fluoride concentration & tensile strain on the corrosion resistance of commercially pure titanium. Biomaterials. 2002;23(1):59-63.

8. Kaneko K, Yokoyama K, Moriyama K, Asaoka K, Sakai J. Delayed fracture of beta titanium orthodontic wires in fluoride aqueous solutions. Biomaterials. 2003;24(12):2113-20.

9. Mane PN, Pawar R, Ganiger C, Phaphe S. Effect of Fluoride Prophylactic agents on the surface topography of NiTi and CuNiTi wires. J Contemp Dent Pract. 2012;13(3):285-8.

10. Wu SK, Wayman CM. Interstitial ordering of hydrogen & oxygen in TiNi alloys. Acta Metallurg. 1988;36(4):1005-13.

11. Nam TH, Shimizu K, Saburi T, Nenno S. Crystal structure of a hydride formed by electrochemical dehydrogenation in a Ti-Ni-Al alloy. Mater Trans JIM. 1989;30(8):539-48.

12. Yokoyama K, Hamada K, Asaoka K. Fracture analysis of hydrogen-charged nicke-titanium superelastic alloy. Mater Trans. 2001;42(1);141-4.

13. Nagumo M. Fundamental aspects of hydrogen embrittlement of iron. Mater Jpn 1994;33(7);914-21.

14. Boyer R, Welhch G, Collings EW. Materials properties handbook: titanium alloys. Materials Park, Ohio: ASM International; 1994.

15. Yokoyama K, Kaneko K, Moriyama K, Asaoka K, Sakai J, Nagumo M. Hydrogen embrittlement of Ni-Ti superelastic alloy in fluoride solution. J Biomed Mater Res A. 2003;65(2):182-7

16. Ogaard B, Rolla G, Arends J. Orthodontic appliances & enamel demineralization. Am Orthod Dentofacial Orthop. 1988;94(1):68-73.

Dental Press Journal of
ORTHODONTICS

Volume 26 - Number 2 - Online

ORIGINAL ARTICLE

https://doi.org/10.1590/2177-6709.26.2.e211945.oar

Can we expect similar behavior among CuNiTi 35°C wires?

Ariane Salgado **GONZAGA**[1]
https://orcid.org/0000-0002-1012-4803
David Salgado **GONZAGA**[2]
https://orcid.org/0000-0002-2830-1556
Hallissa **SIMPLÍCIO**[1]
https://orcid.org/0000-0001-5398-6318
Renato Parsekian **MARTINS**[3]
https://orcid.org/0000-0002-4571-1071
Marília Regalado **GALVÃO**[1]
https://orcid.org/0000-0002-9589-5075
Sergei Godeiro Fernandes Rabelo **CALDAS**[1] ✉
https://orcid.org/0000-0002-1684-5169

Submitted: February 25, 2019 • **Revised and accepted:** September 19, 2019

✉ sergeirabelo@icloud.com

How to cite: Gonzaga AS, Gonzaga DS, Simplício H, Martins RP, Galvão MR, Caldas SGFR. Can we expect similar behavior among CuNiTi 35°C wires? Dental Press J Orthod. 2021;26(2):e211945.

(**1**) Universidade Federal do Rio Grande do Norte, Departamento de Odontologia (Natal/RN, Brazil). (**2**) Universidade Federal do Rio Grande do Norte, Departamento de Engenharia Mecânica (Natal/RN, Brazil). (**3**) Universidade Estadual Paulista, Faculdade de Odontologia de Araraquara (Araraquara/SP, Brazil).

ABSTRACT

Objective: This paper aims to verify the thermodynamic, mechanical and chemical properties of CuNiTi 35°C commercial wires.

Methods: Forty pre-contoured copper-nickel-titanium thermodynamic 0.017 x 0.025-in archwires with an Af temperature of 35°C were used. Eight wires from five different manufacturers (American Orthodontics® [G1], Eurodonto® [G2], Morelli® [G3], Ormco® [G4] and Orthometric® [G5]) underwent cross-sectional dimension measurements, tensile tests, SEM-EDS and differential scanning calorimetry (DSC) tests. Parametric tests (One-way ANOVA and Tukey post-test) were used, with a significance level of 5%, and Pearson's correlation coefficient test was performed between the Af and chemical elements of the wires. All sample tests and statistical analyses were double-blinded.

Results: All wires presented standard dimensions (0.017 x 0.025-in) and superelastic behavior, with mean plateau forces of: G1 = 36.49N; G2 = 27.34N; G3 = 19.24 N; G4 = 37.54 N; and G5 = 17.87N. The Af means were: G1 = 29.40°C, G2 = 29.13°C and G3 = 31.43°C, with $p>0.05$ relative to each other. G4 (32.77°C) and G5 (35.17°C) presented statistically significant differences between each other and among the other groups. All samples presented Ni, Ti, Cu and Al in different concentrations.

Conclusions: The chemical concentration of the elements that compose the alloy significantly influenced the thermodynamic and mechanical properties.

Keywords: Orthodontics. Orthodontic wires. Corrective orthodontics.

RESUMO

Objetivo: O presente artigo teve como objetivo verificar as propriedades termodinâmicas, mecânicas e químicas de fios CuNiTi 35°C comerciais.

Métodos: Foram utilizados 40 arcos termodinâmicos pré-contornados de cobre-níquel-titânio de 0,017" x 0,025" e temperatura Af de 35°C. Oito fios de cinco fabricantes diferentes (American Orthodontics® [G1], Eurodonto® [G2], Morelli® [G3], Ormco® [G4] e Orthometric® [G5]) foram submetidos a medições de suas secções transversais, testes de tração, MEV-EDS e calorimetria diferencial (DSC). Foram utilizados testes paramétricos (One-way ANOVA e pós-teste de Tukey), com nível de significância de 5%, e foi realizado o teste do coeficiente de correlação de Pearson entre a temperatura Af e os elementos químicos dos fios. Todos os testes das amostras e análises estatísticas foram duplo-cegos.

Resultados: Todos os fios apresentavam dimensões padronizadas (0,017" x 0,025") e comportamento superelástico, com forças médias de platô de G1 = 36,49 N; G2 = 27,34 N; G3 = 19,24 N; G4 = 37,54 N; e G5 = 17,87 N. As médias de Af foram: G1 = 29,40°C, G2 = 29,13°C e G3 = 31,43°C, com $p > 0,05$ entre si. G4 (32,77°C) e G5 (35,17°C) apresentaram diferenças estatisticamente significativas entre si e entre os demais grupos. Todas as amostras apresentaram Ni, Ti, Cu e Al em diferentes concentrações.

Conclusões: A concentração química dos elementos que compõem a liga influenciou significativamente as propriedades termodinâmicas e mecânicas.

Palavras-chave: Ortodontia. Fios ortodônticos. Ortodontia corretiva.

INTRODUCTION

Thermodynamic wires are wires that undergo changes in their crystallographic arrangement depending on the relationship between the temperature they are exposed to and their transition temperatures. These inherent temperatures can be manipulated by heat treatments or by atomic substitution, e. g. by replacing part of the nickel or titanium concentration of a nickel-titanium (Ni-Ti) alloy by copper (Cu), resulting in CuNiTi, a tertiary alloy.[1-6] The addition of Cu to NiTi alloys also reduces stress and temperature hysteresis, giving more stability to the superelastic characteristics.[1-6]

Wires manufactured with this alloy have been marketed by Ormco Corporation® under the name of “Copper NiTi”, with three austenite finish temperatures (Af) (27°C, 35°C and 40°C), enabling clinicians to quantify and apply appropriate levels of force for the orthodontic treatment.[1,2] Now at the end of the patent term, several companies with different manufacturing processes, varying prices and possibly different quality manufacture these wires.

Although previous studies have shown a difference in the mechanical and thermodynamic behavior of these wires,[7-9] the origin of these differences has not yet been explained. Thus, the present study analyzed the mechanical, thermodynamic and chemical characteristics of CuNiTi wires from five commercial

brands in an attempt to show which wire characteristics are responsible for the particular behavior among brands of the same cross-sectional diameter.

MATERIAL AND METHODS

The sample consisted of forty 0.017 x 0.025-in pre-contoured CuNiTi wires, with austenitic finish (Af) temperature of 35°C, divided into five groups (G1 to G5), according to their commercial brand, for double-blinded tests (Table 1).

All wires underwent cross-sectional measurements; differential scanning calorimetry (DSC); uniaxial tensile tests; scanning electron microscopy and energy dispersive spectroscopy (SEM/EDS).

Table 1: Distribution of sample groups.

GROUP	NAME	BRAND	LOT
G1	Tanzo	American Orthodontics	C92395
G2	COBRE - NiTi	Eurodonto	F1408000
G3	Thermocopper NiTi	Morelli	2102848
G4	Copper NiTi 35°C	ORMCO	021544059
G5	FlexyNiTi Copper	Orthometric	020917001

CROSS-SECTIONAL MEASUREMENTS

The cross-sectional measurements of the wires were performed using a digital caliper with an accuracy of 0.001 mm (Starret, USA). Five wires randomly selected from each manufacturer were cleaned along with the caliper claws with alcohol, and each one was measured for both height and width at five different points of each archwire.[10]

DIFFERENTIAL SCANNING CALORIMETRY (DSC)

To define the temperature transition range (TTR) of the wires, samples were taken from the straightest portion of each archwire. The samples were cut with orthodontic pliers into lengths of approximately 3 mm and weights of approximately 3.5 mg using a precision electronic scale with an accuracy of 10 µg.[11,12] Each specimen was cleaned with alcohol, dried and placed in a covered and sealed aluminum crucible for a DSC test on a Netzsch Polyma DSC 214 instrument (Selb, Germany). An atmosphere of nitrogen gas at 50ml/min filled the heating chamber and an empty aluminum crucible was the inert reference.[13,14]

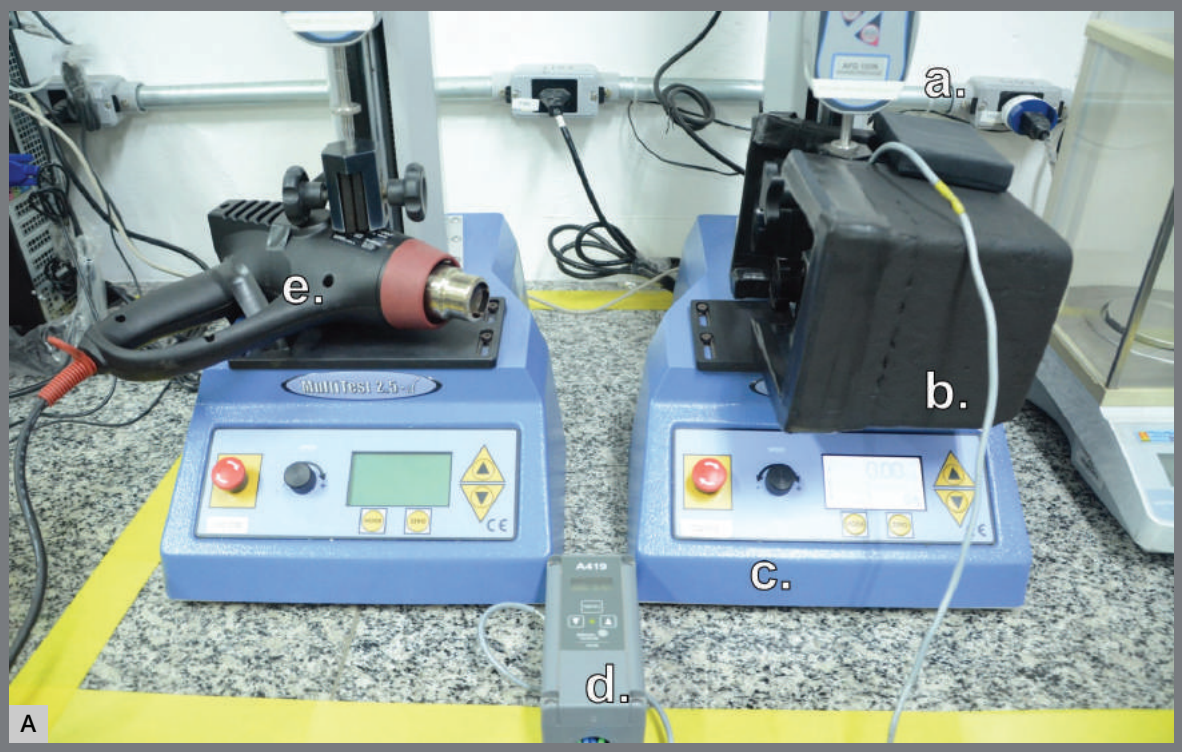
The temperature range of the test was from 60°C to -40°C at 10°C/min. The DSC instrument was connected to Platinum software (TA Instruments, USA) to perform the analyses of the TTRs of exothermic and endothermic reactions, determining the initial and final temperatures of the phases.

UNIAXIAL TENSILE TEST

The mechanical properties of the wires were defined by uniaxial tensile tests on a MultiTest 2.5d universal mechanical testing machine (Mecmesin Corporation, USA) with a 100 N loading cell (Mecmesin Corporation, USA) at the rate of 1mm/min for 2 mm of activation and deactivation. The length of the wire between the grips was 25 mm for all samples, measured with a 0.001-mm precision caliper (Starret®, USA). The samples did not reach the plastic deformation limit, as the deformation carried out was 8% of their initial length.[3,15,16]

Samples damaged by crushing or sliding caused by the mechanical grips were discarded.[4] The whole test was performed under a constant temperature of 37°C, maintained by a 1800 W hot air blower (Bosch®, Holland) at a minimum speed and a distance of 30 cm from the wires, linked to a temperature controller (Johnson Controls® PENN, USA) and with a styrofoam thermal box surrounding the entire clamp system (Fig 1).

The midpoint of a linear regression line in the most horizontal segment of the load/deflection graph of the curves of deactivation in the martensitic phase determined the plateau of forces expressed by the wires, known as the superelastic clinical plateau, with a coefficient of determination of at least 0.99.[5]



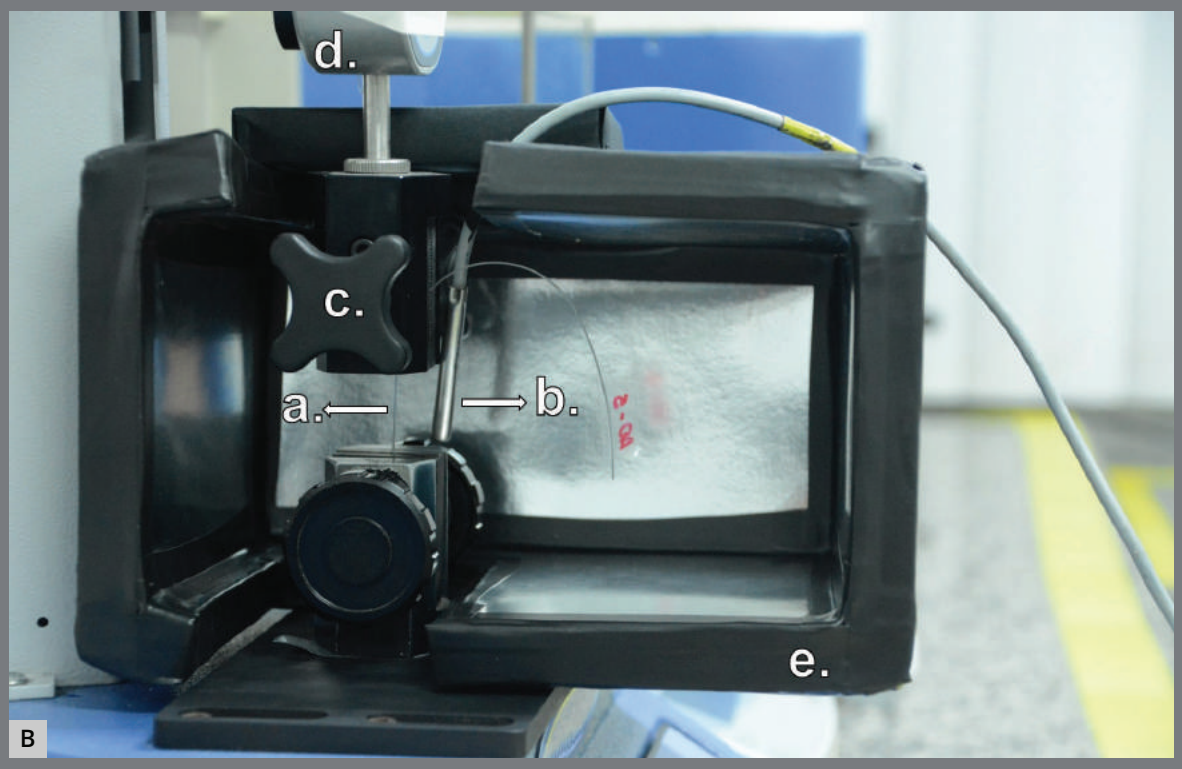


Figure 1: A) Frontal view of the setup of the tensile test with controlled temperature: **a**. load cell; **b**. styrofoam thermal box surrounding the entire clamp system; **c**. MultiTest 2.5d universal mechanical testing machine; **d**. temperature controller; **e**. hot air blower at minimum speed and distance of 30cm from the sample. **B**) View of the clamp system of the tensile test with controlled temperature: **a**. sample attached to the clamps; **b**. thermometer of the temperature controller placed behind the sample; **c**. clamp system; **d**. load cell; **e**. styrofoam thermal box surrounding the entire clamp system.

The superelasticity rate (SE rate) was calculated using the ratio between the elastic modulus of the two lines generated in the deactivation curves of the tested wires (E2/E1). The first elastic modulus (E1) was obtained from the straight line of the superelastic clinical plateau, and the second (E2) was obtained from the first three points of the deactivation curve of the load/deflection graph. Wires presented superelastic behavior when their second SE rate was higher than 8.[5,17]

ENERGY DISPERSIVE SPECTROSCOPY (SEM/EDS)

The microstructure of the wires was observed by SEM/EDS in a T-330 A JEOL-JSM microscope (Toronto Surplus & Scientific Inc., Canada)[18] to determine the superficial chemical composition of the wires in each group and the phases (elements or associations) that compose them. A fractographic image was obtained and the chemical composition was automatically determined in percentages.

STATISTICAL ANALYSIS

Statistical analyses of the data were performed by comparing their normal distribution using the Kolmogorov-Smirnov test. ANOVA One-way and Tukey multiple comparisons tests were carried out considering a significance level of 5%. A Pearson correlation test was performed in order to investigate the correlation between the Af temperature and the chemical elements of the wires. All tests were done on SPSS® software v.11.0 (IBM, USA) for Windows.

RESULTS

CROSS-SECTIONAL MEASUREMENTS

The cross-sectional dimensions were consistent with the information provided by the manufacturers (Table 2).

DIFFERENTIAL SCANNING CALORIMETRY (DSC)

The DSC tests showed that almost all wires presented an Af below that reported by the manufacturers, except group 5: G1) American Orthodontics® = 29.40°C, G2) Eurodonto® = 29.13°C, G3) Morelli® = 31.43°C, G4) Ormco® = 32.77°C and G5) Orthometric® = 35.17°C (Table 3).

Table 2: Measurement of sample dimensions, in inches.

	n	HEIGHT		WIDTH	
		MEAN	SD	MEAN	SD
G1	5	0.017	0.00	0.025	0.00
G2	5	0.017	0.00	0.025	0.00
G3	5	0.017	0.00	0.025	0.00
G4	5	0.017	0.00	0.025	0.00
G5	5	0.017	0.00	0.025	0.00

Table 3: One-way ANOVA and Tukey post-test for DSC tests results. Temperature values in °C.

	n	AS		PEAK A		AF	
		Mean	SD	Mean	SD	Mean	SD
G1	3	9.63^{a}	0.42	19.80^{a}	0.44	29.40^{a}	0.62
G2	3	14.93^{bc}	0.15	22.93^{b}	0.25	29.13^{a}	0.25
G3	3	10.10^{a}	0.82	22.63^{b}	1.02	31.43^{a}	0.95
G4	3	12.90^{a}	0.70	24.17^{a}	0.85	32.77^{b}	0.61
G5	3	17.00^{bc}	1.93	27.53^{b}	1.10	35.17^{c}	0.85

Different letters mean statistically significant differences ($p < 0.05$).

UNIAXIAL TENSILE TEST

The Uniaxial tensile tests showed that all wires presented superelastic behavior. The SE rate and mean plateau force were, respectively: 51.91 and 36.49 N for G1; 30.27 and 27.34 N for G2; 12.11 and 19.24 N for G3; 23.64 and 37.54 N for G4; 21.27 and 17.87 N for G5 (Table 4).

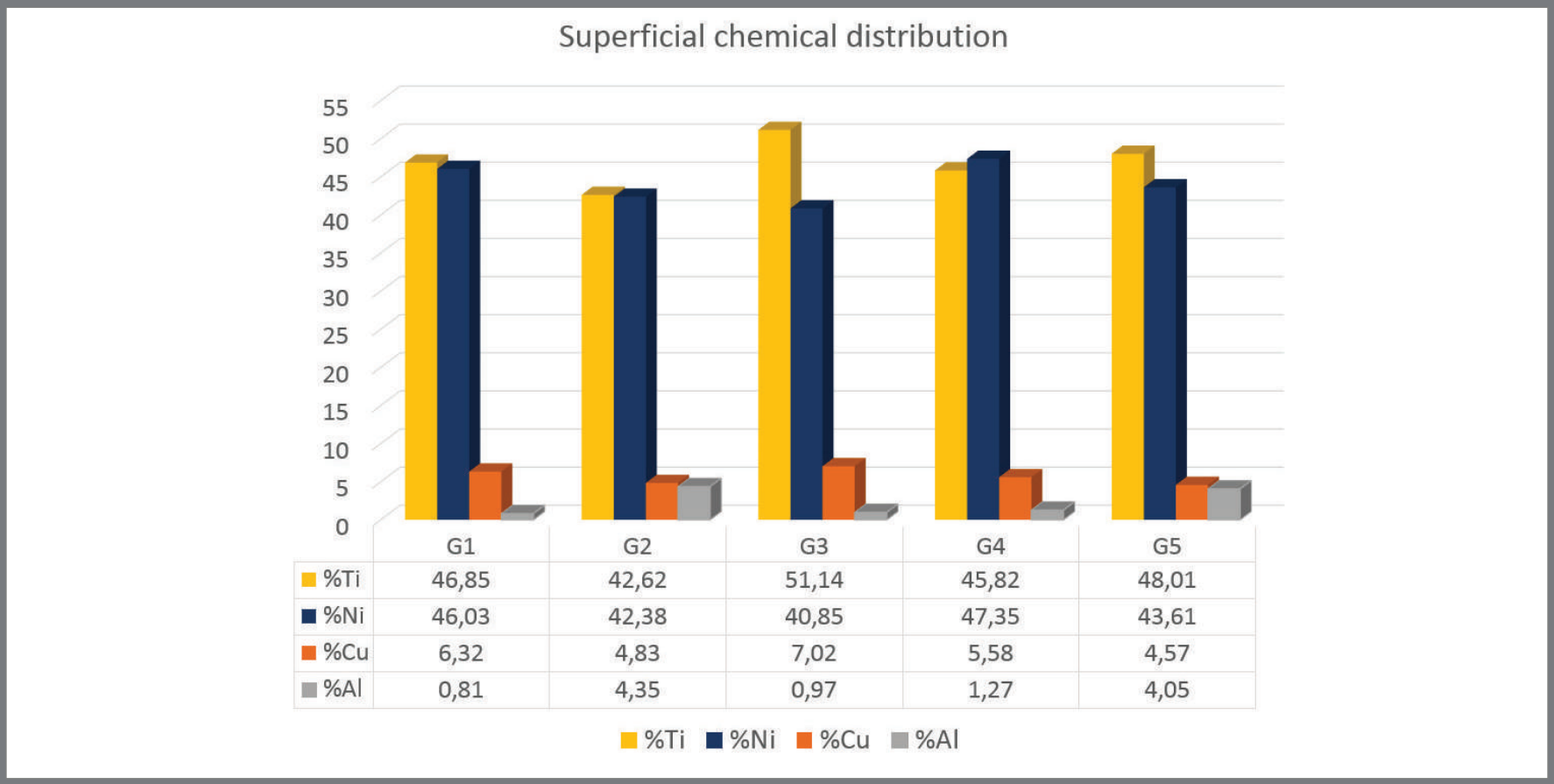
ENERGY DISPERSIVE SPECTROSCOPY (SEM/EDS)

The percentage of titanium (Ti), nickel (Ni), copper (Cu) and aluminum (Al) surface concentrations for the archwires of each manufacturer is given in Figure 2. The Pearson correlation test performed between Af and the chemical elements was not significant ($p > 0.05$).

Table 4: Superelasticity rate (SE Rate) and plateau force in N.

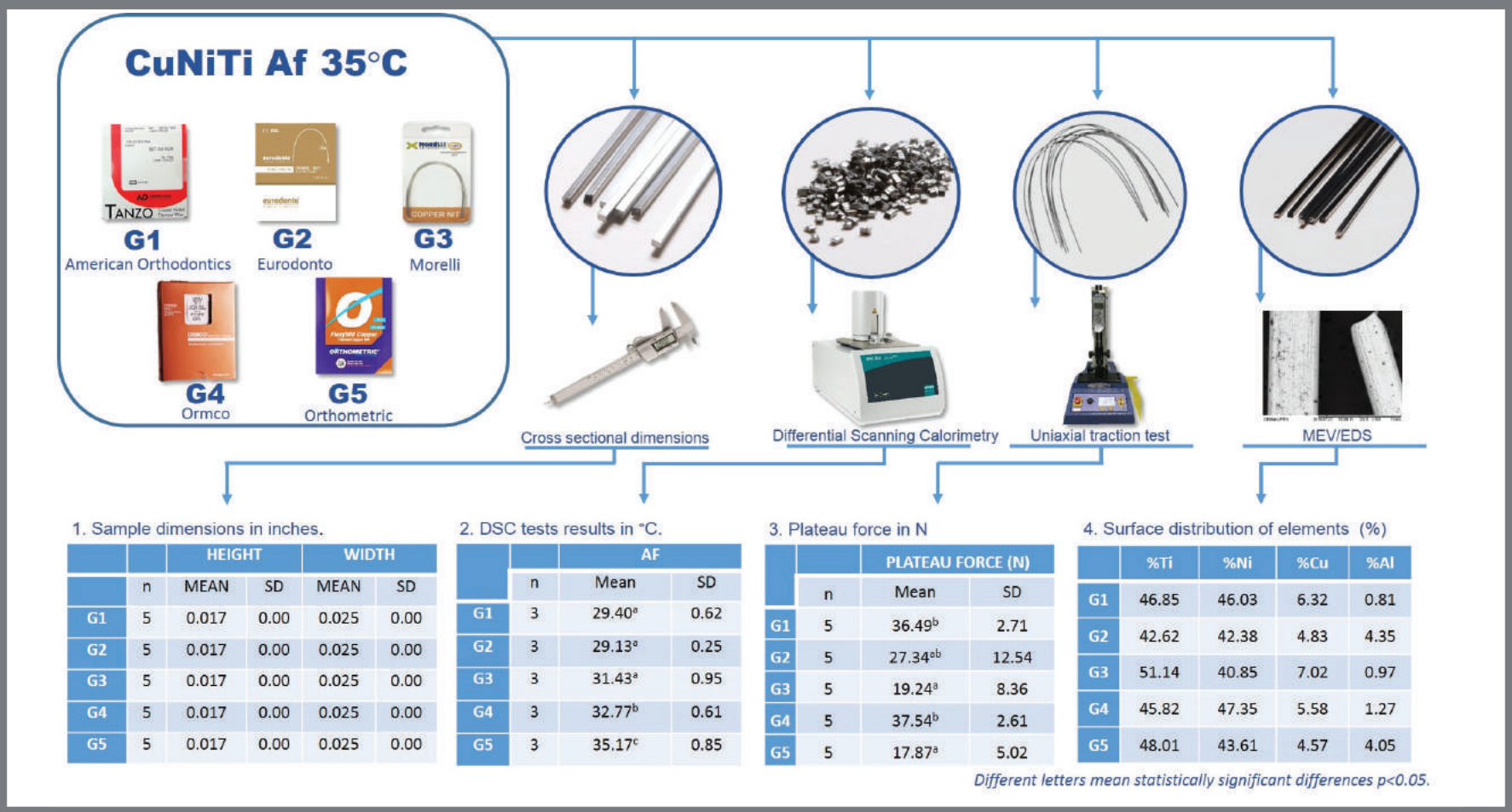
	n	SE RATE		PLATEAU FORCE (N)	
		Mean	SD	Mean	SD
G1	5	51.91	61.62	36.49[b]	2.71
G2	5	30.27	16.29	27.34[ab]	12.54
G3	5	12.11	3.80	19.24[a]	8.36
G4	5	23.64	19.23	37.54[b]	2.61
G5	5	21.27	6.91	17.87[a]	5.02

Different letters mean statistically significant differences (p<0.05).



	G1	G2	G3	G4	G5
%Ti	46,85	42,62	51,14	45,82	48,01
%Ni	46,03	42,38	40,85	47,35	43,61
%Cu	6,32	4,83	7,02	5,58	4,57
%Al	0,81	4,35	0,97	1,27	4,05

Figure 2: Graph of the surface concentration of the chemical elements of the alloys of each manufacturer.



1. Sample dimensions in inches.

		HEIGHT		WIDTH	
	n	MEAN	SD	MEAN	SD
G1	5	0.017	0.00	0.025	0.00
G2	5	0.017	0.00	0.025	0.00
G3	5	0.017	0.00	0.025	0.00
G4	5	0.017	0.00	0.025	0.00
G5	5	0.017	0.00	0.025	0.00

2. DSC tests results in °C.

		AF	
	n	Mean	SD
G1	3	29.40^{a}	0.62
G2	3	29.13^{a}	0.25
G3	3	31.43^{a}	0.95
G4	3	32.77^{b}	0.61
G5	3	35.17^{c}	0.85

3. Plateau force in N

		PLATEAU FORCE (N)	
	n	Mean	SD
G1	5	36.49^{b}	2.71
G2	5	27.34^{ab}	12.54
G3	5	19.24^{a}	8.36
G4	5	37.54^{b}	2.61
G5	5	17.87^{a}	5.02

4. Surface distribution of elements (%)

	%Ti	%Ni	%Cu	%Al
G1	46.85	46.03	6.32	0.81
G2	42.62	42.38	4.83	4.35
G3	51.14	40.85	7.02	0.97
G4	45.82	47.35	5.58	1.27
G5	48.01	43.61	4.57	4.05

Different letters mean statistically significant differences p<0.05.

Figure 3: Graphic summary of materials and methods, and results.

DISCUSSION

When an orthodontic wire with superelastic characteristics is used during orthodontic treatment, the force expressed by this wire on a tooth depends on various factors. These include the temperature at which the transformation of martensite to austenite begins until it reaches the complete transformation (Af) the amount of deformation applied during the activation of this wire, and also the manufacturing processes of the material.[6] Thus, the precise development of variations in the transition temperatures of each wire is one of the essential factors for them to behave clinically as expected, expressing their characteristics of superelasticity and pseudoelasticity. However, if variations in the TTR of the wires due to the manufacturing technique exist, it is possible that the wires produced by different manufacturers express different thermodynamic and mechanical behaviors.[6–8]

Several previous works have already shown that differences among the mechanical behavior of thermoactive archwires of diverse manufacturers and interlot variations are a fact.[4,5,7-9] The novelty of this study lies in its questioning of what variable in the alloy is responsible for the diverse mechanical behavior of the wires that should theoretically express the same patterns (Fig 3).

In order to understand any discrepancies between the wires of different manufacturers analyzed in this study, height

and width of each wire were measured to verify the existence of any dimensional differences. All groups showed standard dimensions (0.017 x 0.025-in), and therefore this factor was excluded as a possible explanation for any behavioral variations.

Among the brands evaluated, only Orthometric® (G5) FlexyNiTi Copper wire reached the Af temperature reported by the manufacturer (35°C), with a statistically significant difference to the other groups. G5 also presented the lowest mean plateau force (17.9N) at deactivation. Therefore, at an oral temperature of 37°C, the wire is expected to be at its final austenitic phase. However, due to the stress-induced martensitic (SIM) transformation during clinical installation, the wire will be expressing its pseudoelasticity. This fact implies the transfer of lower and constant forces during the orthodontic treatment, which is the ideal situation for tooth movement.[1-4,6,18,19,20-23]

This thermal and mechanical behavior can be explained by the chemical composition of the alloy. The concentration of Ti was higher than that of Ni (48.01% and 43.61%), and this difference was the second largest among the evaluated brands. Furthermore, the addition of Cu becomes essential so that the wire has a suitable and stable transition temperature for clinical use.[5,6,19,23,24]

The results showed that the Cu concentration was 4.57% in G5, which was the lowest of all. This low concentration was not expected to present satisfactory results in relation to Af compared to the copper concentrations in the other brands. However, the Al concentration was 4.05%, which was much higher than the other brands, except for G2. This suggest that the association of these chemical elements may have been responsible for the excellent thermodynamic behavior of this wire.

The Pearson correlation test showed that, although weak, there was a negative correlation between Af and Cu (ρ = -0.408), and a positive correlation between Af and Al (ρ = 0.168). This could mean that a higher concentration of Cu in the alloy tends to decrease Af, while the higher concentration of Al in the alloy tends to increase Af, corroborating with the interpretations obtained from the results and other reports.[7,8,9,25]

The Eurodonto® COBRE NiTi wires (G2) showed similar concentrations of Cu and Al (4.83% and 4.35%, respectively); however, their thermal behavior was lower (Af = 29.13°C). In addition, it showed an equiatomic ratio between nickel and titanium (Ni 42.38% and Ti 42.62%), and a plateau force of 27.3N. The fact that there is a balanced ratio between nickel and titanium in these wires already guarantees stability in the thermal and mechanical behavior of this material,[5,24] and no specific treatment is required to prevent decomposition at other phases

of intermediate temperatures[5]. Therefore, it seems safe to say that the addition of copper to the alloy together with aluminum caused a decrease in the variation of the final austenitic temperature, justifying the thermodynamic behavior of these wires.[5,6,19,23-25]

The Tanzo wires from American Orthodontics® (G1) reached a mean high-plateau force of 36.49 N and average Af temperature of 29.4°C; below that identified on their packaging. Similar to the Eurodonto® wires (G2), the SEM-EDS test in this metal alloy showed a superficial chemical composition in which the concentration of Ni and Ti is balanced (46.03% and 46.85%); however, with a Cu concentration equal to 6.32% and a smaller quantity of Al (0.81%). The fact that the Af temperature in this group is practically 7°C below the mean body temperature suggests that the crystalline structure of this metal alloy reached its fully stabilized austenitic phase when inserted into the intraoral environment.[3,5,9,22,25] In the case of this study, this occurred when subjected to a uniaxial traction test with a controlled temperature of 37°C. Thus, apparently the deformation levels required for transforming the final austenitic phase in stress-induced martensitic becomes higher. Therefore, the deformation applied in the study might not have been sufficient for the complete transformation phase to occur, resulting in high values in the tensile test.[1-4,6,18,20-23]

The Morelli® THERMOCOPPER NiTi orthodontic wire samples (G3) presented the second lowest mean plateau force (19.2 N) and an Af temperature of 31.43°C. Its chemical composition revealed the highest concentration of Ti and Cu compared to all groups (51.14% and 7.02%), the lowest concentration of Ni (40.85%) and an Al concentration of 0.97%. The discrepancy between Ni and Ti concentration could generate a thermal behavior with significant variations in Af temperatures. However, the high concentration of Cu in the alloy stabilizes the Af temperature at a value close to that indicated by the manufacturer. This result corroborates with the literature that states that the addition of Cu has the ability to stabilize the TTR, making the thermodynamic behavior less sensitive to Ni and Ti concentrations.[5,6,19,23-25] If the Cu concentration was a little lower in this material and the Al concentration was higher, its Af temperature would probably be closer to 35°C. Such changes would tend to increase the final austenitic temperature value for this wire due to the negative correlation of Af with Cu and the positive correlation with Al. Although these wires have Af temperatures lower than the information provided on their packaging, their mechanical properties were statistically classified as similar to the G5 group. Therefore, their mechanical properties along with their low mean plateau force makes them suitable for clinical use within the specific indications for the use of thermodynamic wires at 35°C.

The evaluations of the Copper Ni-Ti ORMCO® wires (G4) revealed an Af temperature of 32.77°C for this group; this was the second highest of the brands studied, and the highest plateau force average (37.5 N) of all the wires evaluated. In addition to these parameters, G4 was also the only group with a Ni concentration (47.35%, highest of all samples) higher than Ti (45.82%), and it had a Cu concentration of 5.58% and Al equal to 1.27%. Thus, the Cu makes the Af temperature closer to that indicated by the manufacturer.[5,6,19,23-25] However, the low Al concentration, and a relatively low concentration of Ti, which are elements that correlate positively with Af, in addition to the high concentration of Ni, which has a negative correlation with Af, are probably the reasons that this sample expressed high plateau forces and its Af temperature was below 35°C.

Among the results found in this study, the one not expected was the inclusion of aluminum in the alloy, since the manufacturers did not include it in the description of the compositions, naming all wires of this kind as a tertiary alloy – CuNiTi. Nowadays, NiTi and Cu-based alloys are the most studied shape memory alloys (SMAs) in this class of materials, due to their unique thermomechanical behavior. However, despite the preference for NiTi, which is currently the most used SMA, Cu-based SMAs are emerging as potential substitutes, mainly in metallurgical studies for diverse uses, in particular, superelastic $Cu_{17}Al_{11}Mn_4$ that exhibits mechanical properties that are similar to those of

NiTi, but less expensive.[25] Although the literature has shown that binary and tertiary alloys containing Cu and Al in their composition have exhibited excellent thermal and electrical properties, as well as shape memory and superelasticity,[5,25] this information has not been reported in orthodontic wires yet.

Despite the differences found in this study, all the wires evaluated can be used clinically, however, the thermodynamic properties must be considered, in order to enhance the mechanical potential of the wires and optimize the clinical outcomes. Wires with a higher Af temperature demand minor activations to reach the superelastic plateau at deactivation when exposed to body temperature during clinical use, while under the same environmental conditions, those wires with a lower Af temperature need higher activations to express the superelastic plateau at deactivation.

CONCLUSION

According to the results obtained in the study, we can conclude that:

» The chemical concentration of the elements that compose the alloy significantly influenced the thermodynamic and mechanical properties.

» In nickel and titanium equiatomic alloys (G2 and G3), the addition of Cu and Al reduces the TTR, while in non-equiatomic alloys (G1, G4 and G5), the addition of these elements increases the TTR, which is reflected in their Af temperatures.

» Aluminum seems to play a fundamental role in increasing the TTR when the copper concentration is low (G5).

» In the alloys with higher concentrations of Ti (G3 and G5), the deactivation force levels were lower, while in the alloys with higher concentrations of nickel (G4) the deactivation force levels were higher.

» The addition of copper and aluminum to the alloy should be to substitute nickel rather than titanium, to ensure lower levels of deactivation forces.

AUTHORS' CONTRIBUTION

Ariane Salgado Gonzaga (ASG)

David Salgado Gonzaga (DSG)

Hallissa Simplício (HS)

Renato Parsekian Martins (RPM)

Marília Regalado Galvão (MRG)

Sergei G. F. Rabelo Caldas (SGFRC)

Conception or design of the study:

ASG, SGFRC.

Data acquisition, analysis or interpretation:

DSG, HS, RPM, MRG, SGFRC.

Writing the article:

ASG.

Critical revision of the article:

ASG, DSG, HS, RPM, MRG, SGFRC.

Final approval of the article:

ASG, DSG, HS, RPM, MRG, SGFRC.

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

REFERENCES

1. Gil FJ, Planell JA. Effect of copper addition on the superelastic behavior of NiTi shape memory alloys for orthodontic applications. J Biomed Mater Res. 1999;48(5):682-8.

2. Pandis N, Polychronopoulou A, Eliades T. Alleviation of mandibular anterior crowding with copper-nickel-titanium vs nickel-titanium wires: A double-blind randomized control trial. Am J Orthod Dentofac Orthop. 2009;136(2):152.e1152.e7.

3. Santoro M, Nicolay OF, Cangialosi TJ. Pseudoelasticity and thermoelasticity of nickel-titanium alloys: A clinically oriented review. (Part II). Deactivation forces. Am J Orthod Dentofac Orthop. 2001;119(6):594-603.

4. Haider W, Munroe N, Pulletikurthi C, Gill PKS, Amruthaluri S. A comparative biocompatibility analysis of ternary nitinol alloys. J Mater Eng Perform. 2009;18(5-6):760-4.

5. Duerig TW, Melton KN, Stöckel D, Wayman C. Engineering aspects of shape memory alloys. Butterworth-Heinemann Ltda; 1990:498.

6. Quintão CCA, Brunharo IHVP. Fios ortodônticos: conhecer para otimizar a aplicação clínica. Rev Dent Press Ortod Ortop Facial. 2009;14(6):144-57.

7. Santoro M, Beshers DN. Nickel-titanium alloys: Stress-related temperature transitional range. Am J Orthod Dentofac Orthop. 2000;118(6):685-92.

8. Lombardo L, Toni G, Stefanoni F, Mollica F, Guarneri MP, Siciliani G. The effect of temperature on the mechanical behavior of nickel-titanium orthodontic initial archwires. Angle Orthod. 2013;83(2):298-305.

9. Pompei-Reynolds RC, Kanavakis G. Interlot variations of transition temperature range and force delivery in copper-nickel-titanium orthodontic wires. Am J Orthod Dentofac Orthop. 2014;146(2):215-26.

10. Verstrynge A, Van Humbeeck J, Willems G. In-vitro evaluation of the material characteristics of stainless steel and beta-titanium orthodontic wires. Am J Orthod Dentofac Orthop. 2006;130(4):460-70.

11. World Health Organization. International Organization for Standardization, ISO 15841. In: Dentistry-Wires for Use in Orthodontics. 2006:3.

12. ASTM D3418-08, Association Standards Testing Materials. Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry. 2009.

13. Höhne WHG, Hemminger WH, Flammersheim HJ. Differential scanning calorimetry: an introduction for practitioners. Springer-Verlog. 2004:298.

14. Spini TS, Valarelli FPFP, Cançado RH, Freitas KMS, Villarinho DJ, Freitas KMS de. Transition temperature range of thermally activated nickel-titanium archwires. J Appl Oral Sci. 2014;22(2):109-17.

15. World Health Organization. International Organization for Standardization, ISO 6892. In: 1 Metallic Materials: Tensile Testing (Part 1). Method of Test at Room Temperature. 2009:65.

16. Gravina MA, Brunharo IHVP, Canavarro C, Elias CN, Quintão CCA. Mechanical properties of NiTi and CuNiTi wires used in orthodontic treatment. (Part 1). Stress-strain tests. Dental Press J Orthod. 2013; July-Aug;18(4):35-42.

17. Vieira CIV, Caldas SGFR, Martins LP, Martins RP. Superelasticity and force plateau of nickel-titanium springs : an in vitro study. Dental Press J Orthod. 2016;21(3):46-55.

18. Okamoto Y, Hamanaka H, Miura F, Tamura H, Horikawa H. Reversible changes in yield stress and transformation temperature of a NiTi alloy by alternate heat treatments. Scr Metall. 1988;22(4):517-20.

19. Gravina MA, Canavarro C, Elias CN, Chaves MDGAM, Brunharo IHVP, Quintão CCA. Mechanical properties of NiTi and CuNiTi wires used in orthodontic treatment. (Part 2). Microscopic surface appraisal and metallurgical characteristics. J Orthod. 2014;19(1):69-76.

20. Miura F, Mogi M, Ohura Y, Hamanaka H. The super-elastic property of the Japanese NiTi alloy wire for use in orthodontics. Am J Orthod Dentofac Orthop. 1986;90(1):1-10.

21. Miura F, Mogi M, Ohura Y, Karibe M. The super-elastic Japanese NiTi alloy wire for use in orthodontics part III. Studies on the Japanese NiTi alloy coil springs. Am J Orthod Dentofac Orthop. 1988;94(2):89-96.

22. Burstone CJ, Qin B, Morton JY. Chinese NiTi wire: A new orthodontic alloy. Am J Orthod. 1985;87(6):445-52.

23. Fischer-Brandies H, Es-Souni M, Kock N, Raetzke K, Bock O. Transformation behavior, chemical composition, surface topography and bending properties of five selected 0.016“ x 0.022” NiTi archwires. J Orofac Orthop. 2003;64(2):88-99.

24. Wang J, Juni W, Cao MZ, Yang R. Transformation behavior of Ti50-x/2Ni50x/2Cux alloys. Acta Metall Sin (Engl Lett). 2006 Dec;19(6), 391-6.

25. Oliveira JP, Zeng Z, Omori T, Zhou N, Miranda RM, Fernandes FMB. Improvement of damping properties in laser processed superelastic Cu-Al-Mn shape memory alloys. Mater Des. 2016;98:280-84.

Dental Press Journal of
ORTHODONTICS

Volume 26 - Number 2 - Online

ORIGINAL ARTICLE

https://doi.org/10.1590/2177-6709.26.2.e211955.oar

Chromatic analysis of orthodontic resin bonding agents exposed to different antiseptic mouthrinses

Alana Dantas **MOREIRA**[1]
https://orcid.org/0000-0002-5481-2712

Jamille Barros **FERREIRA**[1]
https://orcid.org/0000-0002-7679-7517

Claudia Trindade **MATTOS**[2]
https://orcid.org/0000-0001-5975-0680

Mariana **MARQUEZAN**[3]
https://orcid.org/0000-0001-6078-5194

Mônica Tirre de Souza **ARAÚJO**[1]
https://orcid.org/0000-0002-4064-8122

Eduardo Franzotti **SANT'ANNA**[1]✉
https://orcid.org/0000-0002-4167-6694

Submitted: 19 February, 2019 • **Revised and accepted:** 24 September, 2019

✉eduardo.franzotti@gmail.com

How to cite: Moreira AD, Ferreira JB, Mattos CT, Marquezan M, Araújo MTS, Sant'Anna EF. Chromatic analysis of orthodontic resin bonding agents exposed to different antiseptic mouthrinses. Dental Press J Orthod. 2021;26(2):e211955.

(1) Universidade Federal do Rio de Janeiro, Departamento de Odontopediatria e Ortodontia (Rio de Janeiro/RJ, Brazil). (2) Universidade Federal Fluminense, Departamento de Ortodontia (Niterói/RJ, Brazil). (3) Universidade Federal de Santa Maria, Departamento de Estomatologia (Santa Maria/RS, Brazil).

ABSTRACT

Objective: To assess the color of different orthodontic resin bonding agents exposed to three antiseptic mouthrinses for a prolonged time interval (10-year aging simulation). **Methods:** 160 specimens were distributed into four groups, according to the orthodontic resin bond agent (Concise, Transbond XT, Transbond Plus Color Change, and Natural Ortho). Each group was exposed to different antiseptic mouthrinses: alcohol-based (Listerine®), alcohol-free (Oral-B®), chlorhexidine (Periogard®) and distilled water as the control. Specimens were submitted to two cycles of staining and artificial aging. Color was evaluated by means of a digital spectrophotometer at the beginning of the experiment and after every cycle. The system used to assess color changes was the CIE L*a*b*. Data was analyzed using the ANOVA and Tukey *post-hoc* test. **Results:** After simulation of 10 years of aging, Transbond XT and Natural Ortho composites presented no statistically significant differences in ΔE when exposed to different mouthrinses. The Concise composite specimens exposed to alcohol-free mouthrinse presented a significant difference when compared with specimens from the same group exposed to other antiseptic mouthrinses. Transbond Plus Color Change specimens exposed to chlorhexidine mouthrinse and to alcohol-containing mouthrinse presented a significant difference when compared with the specimens from the group exposed to water and alcohol-free antiseptic. **Conclusion:** All orthodontic resin bonding agents tested presented clinically perceptible color changes when exposed to at least one of the mouthrinses, except for the Natural Ortho composite. The Concise composite exposed to the alcohol-free solution was the resin that presented the highest color change values.

Keywords: Orthodontics. Resins, synthetic. Mouthwashes.

RESUMO

Objetivo: Avaliar a cor de diferentes resinas ortodônticas expostas a três enxaguantes bucais, por um intervalo de tempo prolongado (simulação de 10 anos de envelhecimento). **Métodos:** 160 espécimes foram distribuídos em quatro grupos, de acordo com a resina de colagem ortodôntica (Concise, Transbond XT, Transbond Plus Color Change e Natural Ortho). Cada grupo foi exposto a diferentes tipos de enxaguantes bucais: à base de álcool (Listerine®), isento de álcool (Oral-B®), clorexidina (Periogard®) ou água destilada, como controle. Os espécimes foram submetidos a dois ciclos de manchamento e envelhecimento artificial. A cor foi avaliada por meio de um espectrofotômetro digital no início do experimento e após cada ciclo. O sistema utilizado para avaliar as alterações de cor foi o CIE L*a*b*. Os dados foram analisados utilizando-se o teste ANOVA e o teste *post-hoc* de Tukey. **Resultados:** Após a simulação de 10 anos de envelhecimento, as resinas Transbond XT e Natural Ortho não apresentaram diferenças estatisticamente significativas no ΔE, quando expostas a diferentes enxaguantes bucais. Os espécimes do grupo Concise expostos ao enxaguante bucal sem álcool apresentaram diferença significativa quando comparados aos espécimes do mesmo grupo expostos aos outros enxaguantes bucais. Os espécimes do grupo Transbond Plus Color Change expostos à clorexidina e ao enxaguante bucal à base de álcool apresentaram diferença significativa quando comparados aos espécimes dos grupos expostos à água e ao enxaguante bucal sem álcool. **Conclusão:** Todas as resinas ortodônticas avaliadas apresentaram alterações de cor clinicamente perceptíveis quando expostas a pelo menos um dos enxaguantes bucais, com exceção da resina ortodôntica Natural Ortho. A resina Concise exposta à solução isenta de álcool foi a que apresentou os maiores valores de alteração de cor.

Palavras-chave: Ortodontia. Resinas dentárias. Antissépticos bucais.

INTRODUCTION

The constant evolution of techniques, materials and concepts in Dentistry demands that dentists keep up to date with these innovations. This is especially important with regard to new trends in esthetics, considering factors that include tooth color, shape and alignment, as well as facial expressions and gingival appearance.[1] A more demanding orthodontic patient is also generally concerned with a possible tooth color change during and after treatment. Depending on the frequency and period of exposure to agents that affect color, some environmental factors may cause changes in esthetics during treatment.[2]

The main purpose of using antiseptic mouthrinses is to control the development and progression of periodontal disease and caries. However, their frequent use may lead to adverse effects on teeth and oral tissues,[3,4,5] including chromatic changes. As a result, several studies have analyzed the color stability of dental materials exposed to alcohol-containing, alcohol-free and chlorhexidine antiseptic mouthrinses.[3,5-8]

Alcohol and chlorhexidine have unique characteristics that have contributed to their addition to mouthrinse solutions and both have antiseptic properties. Alcohol helps the breakdown or dissolution of active principles and preserves the components of the formula. Chlorhexidine is capable of denaturing

the components of biofilm. Among their disadvantages and side effects, alcohol may be responsible for lesions in oral tissues and softening of resin composites;[9,10] and chlorhexidine may be associated with changes in sensitivity, superficial peeling of the oral mucosa, calculus formation and change in color of the tongue and teeth, resulting from the precipitation of dietary pigments.[4,11]

The lack of color stability of orthodontic resin bonding agents is a main source of tooth darkening or staining. Acid conditioning on dental enamel performed before the procedure of bonding orthodontic fixed appliances to the teeth results in an increase in microporosities on their surface. When these microporosities are filled with resin, tags (resin extension within the dental enamel) are created, and the depth and thickness of these tags is highly variable, with their mean size ranging from 11.8 μm to 18.9 μm. Many tags may reach a depth of 89 μm to 100 μm[12]. These tags are intended to provide retention between the orthodontic bonding agent and the tooth, and they may remain in the dental enamel permanently. Nevertheless, the aging process in addition to pigments present in a person's diet, and chemical products used in the oral cavity may alter the color of these composites, leading to poor esthetics.[13]

Additionally, it is commonplace for a certain amount of excess resin bonding agent flash to remain on the bracket edges; between the bracket and the enamel, during bracket bonding.[14] Armstrong et al.[14] observed that even the addition of a color change feature in the bonding agent does not guarantee a reduction in the amount of excessive resin bonding agent accumulating around orthodontic brackets. Therefore, the color change in these excessive orthodontic bonding agents could be esthetically important during orthodontic treatment, particularly in the anterior teeth.

Thus, the aim of this study was to perform an *in vitro* chromatic analysis of orthodontic resin bonding agents exposed to different antiseptic mouthrinses for a prolonged time interval.

MATERIAL AND METHODS

In this study, 160 5mm-diameter and 2mm-high disc-shaped specimens were made from four different orthodontic resin bonding agents and divided into four groups, according to the orthodontic resin. All specimens obtained were immersed in distilled water at a temperature of 37°C for 24 hours, in order to ensure complete polymerization.[6]

Each group consisted of 40 specimens that were made from each of the following bonding agents: 1) Concise composite chemical cure resin bonding agent (3M Unitek, Monrovia, USA), 2) Transbond XT light cure resin bonding agent (3M Unitek, Monrovia, USA), 3) Transbond Plus Color Change light cure resin bonding agent (3M Unitek, Monrovia, USA) and 4) Natural Ortho light cure orthodontic resin bonding agent (DFL, Rio de Janeiro, Brazil). Ten specimens of each group were exposed to different mouthrinses: an alcohol-containing (21.6%) mouthrinse (Listerine®, Tartar Control, Johnson & Johnson, São Paulo, Brazil); an alcohol-free antiseptic (cetylpyridinium chloride) mouthrinse (Oral-B®, Mint flavor, Procter & Gamble, São Paulo, Brazil); a chlorhexidine (0.06%) mouthrinse (Periogard®, Colgate-Palmolive, São Paulo, Brazil); and distilled water served as control.[3] All mouthrinses tested had a blue color.

All specimens, immersed in their respective solutions, were submitted to two cycles of staining and artificial aging in an aging chamber with ultraviolet light (wavelength of 254 nm), under heat (45°C) and 65% relative humidity (according to ADA Standard n. 27), for 24 hours. Each cycle corresponded to 5 years of aging in the mouth. During the interval between cycles and at the end of the experiment, the specimens were immersed in distilled water.

The color of specimens was assessed with a portable digital spectrophotometer[3,6] Vita Easyshade® Compact (VITA Zahnfabrik H. Rauter GmbH Co. KG, Bad Säckingen, Germany – Model DEASYC220) at two time intervals: initial (T_0) – before their immersion in the respective solutions; and after the second cycle (T_1). The measurements were made in the same environment by a single, previously calibrated operator. Three color measurements were taken of each specimen at each time interval, and the mean of these values was considered.[3]

The Commission Internationale de L'Eclairage (CIE L*a*b*)[15,16] defined a system of color reading, where L* represents the luminosity axis (from black to white). The chroma is described by two variables: a* and b*; a* represents the green-red axis (-a = green; +a = red), and b* represents the blue-yellow axis (-b = blue; +b = yellow). Thus, the calculation of total color change (ΔE*ab) was possible by using the following formula: $\Delta E^*ab = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$. The values of L*, b* and ΔE* were compared.[16]

The results obtained were analyzed using the Kolmogorov-Smirnov normality test. Analysis of variance (ANOVA) and the Tukey *post-hoc* tests were used to identify differences between groups in each period. The paired-samples *t*-test was used to identify differences related to mouthrinses in each group between time intervals, compared to distilled water.

RESULTS

All four resins showed some color change when immersed in any of the tested solutions, however, the resins presented different behavior when exposed to the individual solutions. Considering ΔE values, Concise resin showed a more significant color change only when immersed in Oral-B rinse. Transbond Plus Color Change showed higher color change values when immersed in Oral-B and Periogard. Transbond XT and Natural Ortho, on the other hand, showed no statistically significant difference, regardless of the solutions in which they were immersed (Table 1).

Table 1: Descriptive statistics and comparisons of ΔE values among different resins and among mouthrinses after the two cycles of staining and artificial aging (T1).

	Concise	Transbond XT	Transbond Plus Color Change	Natural Ortho
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Distilled water	2.55 (0.93)^{ABa}	3.25 (1.72)^{Ba}	2.50 (1.04)^{ABa}	1.35 (1.38)^{Aa}
Listerine®	3.31 (1.31)^{ABa}	3.64 (1.35)^{Ba}	2.68 (0.96) ^{ABa}	1.99 (0.92)^{Aa}
Oral-B®	6.32 (2.54)^{Ab}	3.64 (0.97)^{Ba}	2.92 (1.09)^{Bab}	2.53 (0.92)^{Ba}
Periogard®	2.29 (0.83)^{Aa}	2.59 (1.13)^{Aa}	3.86 (0.60)^{Bb}	1.55 (0.98)^{Aa}

^{A,B} Comparison among resins (each line express a different test).

^{a,b} Comparison among mouthrinses (each column express a different test).

Different letters mean statistically significant difference ($p<0.05$).

When resins were immersed in water (control), only Transbond XT showed a significant change in ΔE. When immersed in Listerine, the most significant color change was observed for Transbond XT, and Natural Ortho showed the least significant change. Oral-B caused higher color change values in Concise, while Periogard was the strongest color change mouthrinse on Transbond Plus Color Change (Table 1).

The comparison between initial and final L values found for the Concise specimens showed a statistically significant difference among all mouthrinses studied. Transbond XT and Transbond Plus Color Change specimens exposed to the Listerine® solution and to Periogard® showed statistically significant difference between the initial and final L values.. The comparison between initial and final L values found for the Natural Ortho specimens showed a statistically significant difference when exposed to the Listerine® solution (Table 2).

Table 2: Descriptive statistics (mean and standard deviation) and comparisons of L values between mouthrinses in each group after the two cycles of staining and artificial aging.

Solutions	Concise		Transbond XT		Transbond Plus Color Change		Natural Ortho	
	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1
Distilled water	90.27 (0.74)[a]	88.33 (1.03)[b]	86.55 (0.15)[a]	86.32 (0.34)[a]	93.77 (1.01)[a]	93.32 (0.68)[a]	95.72 (0.55)[a]	95.46 (0.54)[a]
Listerine®	90.22 (1.06)[a]	89.38 (1.31)[b]	86.74 (0.63)[a]	85.98 (0.55)[b]	94.24 (0.93)[a]	93.85 (1.23)[b]	95.60 (0.65)[a]	95.05 (0.60)[b]
Oral-B®	90.68 (1.17)[a]	87.57 (2.40)[b]	86.82 (0.41)[a]	86.75 (0.68)[a]	93.21 (0.56)[a]	93.31 (0.83)[a]	95.91 (0.73)[a]	95.56 (0.76)[a]
Periogard ®	86.69 (0.91)[a]	88.91 (0.67)[b]	86.62 (0.39)[a]	86.25 (0.35)[c]	94.60 (1.35)[a]	93.71 (1.13)[b]	95.71 (0.94)[a]	95.72 (0.88)[a]

[a,b] Comparison among the mouthrinses (each column express a different test).

Different letters mean statistically significant difference ($p<0.05$).

Table 3: Descriptive statistics (mean and standard deviation) and comparisons of b* values between mouthrinses in each group after the two cycles of staining and artificial aging.

Solutions	Concise		Transbond XT		Transbond Plus Color Change		Natural Ortho	
	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1
Distilled water	25.48 (0.64)[a]	26.73 (1.35)[b]	16.04 (2.27)[a]	13.60 (1.42)[b]	19.14 (1.32)[a]	16.99 (0.71)[b]	16.51 (1.02)[a]	15.43 (0.91)[b]
Listerine®	24.89 (1.25)[a]	27.75 (1.33)[b]	15.12 (1.66)[a]	11,68 (0,56)[b]	17.97 (0.98)[a]	15.77 (1.13)[c]	16.14 (1.11)[a]	14.78 (0.96)[b]
Oral-B®	23.72 (1.10)[a]	23.61 (1.85)[a]	14.40 (1.01)[a]	10.82 (0.64)[b]	17.86 (0.69)[a]	15.68 (1.34)[c]	15.97 (1.07)[a]	13.54 (0.66)[c]
Periogard ®	24.60 (1.01)[a]	25.86 (0.81)[c]	14.70 (1.52)[a]	12.21 (1.10)[b]	17.96 (0.74)[a]	14.62 (0.49)[b]	15.78 (1.24)[a]	14.43 (0.82)[b]

[a,b] Comparison among the mouthrinses (each column express a different test).

Different letters mean statistically significant difference ($p<0.05$).

Comparison between the initial and final b* values of the Concise specimens showed a statistically significant difference for all the mouthrinses studied, except for Oral-B® solution. Transbond XT, Transbond Plus Color Change and Natural Ortho specimens showed a statistically significant difference between the initial and final b* values when immersed in any of the mouthrinses studied and distilled water (Table 3).

DISCUSSION

Visual color perception is essentially a subjective matter, which may be physiologically and psychologically influenced, and may be different for each researcher willing to assess color changes. Some of the factors that may influence visual color assessment and contribute to this subjectivity are: the distance between the object and the observer, the color of

the light used for illumination, the metamerism phenomenon, fatigue and aging of the object, and even the emotional state of the observer.[17] In this context, the use of a spectrophotometer eliminates the errors of subjective color assessment.

The ΔE values are frequently used to assess color change between two time intervals, although they do not reveal specifically where this change lies. Some authors consider a ΔE value of 3.3 as the threshold, after which the color change becomes visually perceptible,[18,19] while other authors have adopted the value of 3.7 as the threshold.[20,21] The ΔE limit value considered in this study was 3.3.

Concise specimens exposed to the Oral-B® solution presented the highest ΔE values (6.32) among all specimens and solutions studied. The specimens of the same composite exposed to the Listerine® solution also showed a clinically perceptible color change (ΔE = 3.31), but to a lower degree. Transbond XT specimens showed an equally perceptible change (ΔE = 3.64) when submitted to both Oral-B® and Listerine® solutions. Transbond Plus Color Change specimens, however, only presented ΔE values (3.86) that characterized a clinically perceptible color change when they were exposed to the Periogard® solution. Natural Ortho specimens presented no visually perceptible color changes, according to the threshold of ΔE considered in this study (3.3).[18,19]

Luminosity is the most important factor in determining color, as colors with low luminosity values appear to be darker. The assessment of L* values allowed the analysis of whether the studied resin bonding agents became lighter or darker. When the L* values rose, this meant that the luminosity increased, and the object became lighter. When the L* values decreased, this meant that there was a reduction in the luminosity and the object became darker. Changes in the L* values are the most significant parameter in color change, as the human eye may detect these changes more easily than changes in other parameters, such as the a* and b* values. Any change in L* values below 2.0 is not clinically visible.[21]

All bonding agents assessed in this study became darker or showed no difference in luminosity after the two cycles of staining and artificial aging, when immersed in distilled water and when they were exposed to different mouthrinses. The only exception was the Transbond Plus Color Change specimens exposed to the Oral-B® solution, which showed a discrete increase in luminosity that was not statistically significant.

Since b* values may represent a yellow (positive values) or a blue (negative values) hue, analysis of the b* values in this study showed that Transbond XT, Transbond Plus Color Change and Natural Ortho specimens presented a color change tending towards a blue hue, confirmed by the reduction in b* values

after the two cycles of staining and artificial aging. However, Concise composite specimens presented a decrease in b* values only when exposed to the Oral-B® solution. The specimens exposed to Listerine® and Periogard® solutions, as well as to distilled water, showed an increase in b* values, indicating a color change tending towards a yellow hue by the end of the experiment.

In this study, the effect of an alcohol-containing mouthrinse, an alcohol-free antiseptic mouthrinse and a chlorhexidine mouthrinse on color stability of different orthodontic resin bonding agents was assessed. Villalta et al.[22] noted that a low pH and a high alcohol concentration in solutions may affect the surface integrity and stain dental composite resins. In this study, two orthodontic bonding agents (Transbond XT and Concise) submitted to the alcohol-containing solution Listerine® presented a perceptible color change, and two (Transbond Plus Color Change and Natural Ortho) presented an imperceptible color change. Chlorhexidine may denature the components of biofilm, accelerating the formation of pigmented sulfides and precipitating pigments from diet.[9] In this *in vitro* study, the use of food or diet was not included, so that the lack of staining in specimens submitted to the chlorhexidine solution Periogard® could be justified. Whereas, one bonding agent (Transbond Plus Color Change) presented a clinically perceptible color change when exposed to the chlorhexidine solution Periogard®.

According to Eliades et al,[13] one of the sources of exogenous discoloration of polymeric materials may be the superficial absorption of color pigmentation from colored mouthrinses, even though the discoloration of these materials may originate from a wide array of exogenous or endogenous sources. The effect of antiseptic solutions on composite color change may be material-dependent and the resin susceptibility to staining may be attributed to its matrix. Some authors have shown that the type of material played a significant role in resistance to staining.[3] Likewise, in this study, different types of orthodontic resin bonding agents showed different behaviors when exposed to antiseptic mouthrinses and submitted to two cycles of artificial aging and staining.

Clinicians should thus be aware of the properties of the orthodontic resin bonding agents they use, in order to indicate a more compatible mouthrinse that affects it the least. Remnants of orthodontic resin bonding agents around metal orthodontic brackets, which become stained, may impair esthetics during orthodontic treatment. In addition, this staining may become even more evident in the remaining orthodontic resin bonding agents located around translucent esthetic brackets. After orthodontic treatment and bracket debonding, resin tags remain on enamel surface, so the esthetic appearance and color stability of the resin continue to be cause for concern.

Therefore, to enable clinicians to maintain esthetics during and after orthodontic treatment, it is essential for them to know which orthodontic resin bonding agents are more likely to be stained with certain mouthrinses.

The results of this study showed that antiseptic mouthrinses may cause chromatic changes in orthodontic resin bonding agents. However, in general, the specific presence of alcohol or chlorhexidine in these solutions did not seem to trigger these color changes.

In vivo studies are necessary to observe the effect of antiseptic mouthrinses on orthodontic resin bonding agents under clinical conditions, as some factors such as saliva, biofilm and diet may not be adequately reproduced *in vitro* and may influence the physical and esthetic properties of resins.

CONCLUSION

Orthodontic resin bonding agents tested presented clinically perceptible color changes when exposed to at least one of the tested mouthrinses, except for the Natural Ortho bonding agent, which showed no visually perceptible color changes.

The Concise bonding agent exposed to the alcohol-free solution was the resin that showed the highest color change values, which differed statistically from that of the other resins observed in the study.

AUTHORS' CONTRIBUTION

Alana Dantas Moreira (ADM)

Jamille Barros Ferreira (JBF)

Claudia Trindade Mattos (CTM)

Mariana Marquezan (MM)

Mônica Tirre de S. Araújo (MTSA)

Eduardo Franzotti Sant'Anna (EFSA)

Conception or design of the study:

ADM, JBF, CTM, MM, MTSA, EFSA.

Data acquisition, analysis or interpretation:

ADM, JBF, CTM, MM, MTSA, EFSA.

Writing the article:

ADM, JBF, CTM, MM, MTSA, EFSA.

Critical revision of the article:

ADM, JBF, CTM, MM, MTSA, EFSA.

Final approval of the article:

ADM, JBF, CTM, MM, MTSA, EFSA.

Fundraising:

EFSA.

Overall responsibility:

EFSA.

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

REFERENCES

1. Lawson J, Warren JJ, Levy SM, Broffitt B, Bishara SE. Relative esthetic importance of orthodontic and color abnormalities. Angle Orthod. 2008;78:889-94.

2. Kumar MS, Ajay R, Sahib SAM, Chittrarasu M, Navarasu M, Ragavendran N, et al. Color stability assessment of two different composite resins with variable immersion time using various beverages: an in vitro study. J Pharm Bioallied Sci. 2017; 9(Suppl 1): S161–S165.

3. Celik C, Yuzugullu B, Erkut S, Yamanel K. Effects of mouthrinses on color stability of resin composites. Eur J Dent. 2008;2:247-53.

4. Gagari E, Kabani S. Adverse effects of mouthrinse use. A review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1995;80:432-9.

5. Elembaby AE. The effects of mouthrinses on the color stability of resin-based restorative materials. J Esthet Restor Dent. 2014;26:264-71.

6. Gürdal P, Akdeniz BG, Hakan Sen B. The effects of mouthrinses on microhardness and colour stability of aesthetic restorative materials. J Oral Rehabil. 2002;29:895-901.

7. Lee YK, El Zawahry M, Noaman KM, Powers JM. Effect of mouthrinse and accelerated aging on the color stability of esthetic restorative materials. Am J Dent. 2000;13:159-61.

8. Khosravi M, Esmaeili B, Nikzad F, Khafri S. Color stability of nanofilled and microhybrid resin-based composites following exposure to chlorhexidine mouthrinses: an in vitro study. J Dent. 2016;13:116-25.

9. Lemos CA Jr, Villoria GE. Reviewed evidence about the safety of the daily use of alcohol-based mouthrinses. Braz Oral Res. 2008;22 Suppl 1:24-31.

10. Gürgan S, Onen A, Köprülü H. In vitro effects of alcohol-containing and alcohol-free mouthrinses on microhardness of some restorative materials. J Oral Rehabil. 1997; 24:244-6.

11. Watts A, Addy M. Tooth discolouration and staining: a review of the literature. Br Dent J. 2001;190:309-16.

12. Menezes L, Chevitarese O. Sealant and resin viscosity and their influence on the formation of resin tags. Angle Orthod. 1994;64:383-8.

13. Eliades T, Gioka C, Heim M, Eliades G, Makou M. Color stability of orthodontic resin bonding agent resins. Angle Orthod. 2004;74:391-3.

14. Armstrong D, Shen G, Petocz P, Darendeliler A. Excess resin bonding agent flash upon bracket placement. Angle Orthod. 2007;77:1101-8.

15. Marquezan M, Chaves IBBM, Lima Filho HL, Freitas AOA, Ruellas ACO. Shear strength of brackets bonded to acrylic teeth using different surface conditioning and bonding materials. Int J Contemp Dent. 2017;8:1-5.

16. CIE-Colourimetry. Official Recommendations of the International Commision on Illumination. Publication CIE (supplement 21). Paris, France: Bureau Central de la CIE; 1978;15-30.

17. Yannikakis SA, Zissis AJ, Polyzois GL, Caroni C. Color stability of provisional resin restorative materials. J Prosthet Dent. 1998;80:533-9.

18. Um CM, Ruyter IE. Staining of resin-based veneering materials with coffee and tea. Quintessence Int. 1991;22:377-86.

19. Uchida H, Vaidyanathan J, Viswanadhan T, Vaidyanathan TK. Color stability of denture composites as a function of shade. J Prosthet Dent. 1998;79:372-7.

20. Eliades T, Kakaboura A, Eliades G, Bradley TG. Comparison of enamel colour changes associated with orthodontic bonding using two different resin bonding agents. Eur J Orthod. 2001;23:85-90.

21. Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical colorimetry. J Dent Res.1989;68:819-22.

22. Villalta P, Lu H, Okte Z, Garcia-Godoy F, Powers JM. Effects of staining and bleaching on color change of dental composite resins. J Prosthet Dent. 2006;95:137-42.

Dental Press Journal of
ORTHODONTICS

Volume 26 - Number 2 - Online

ORIGINAL ARTICLE

https://doi.org/10.1590/2177-6709.26.2.e2119187.oar

Factors affecting the stability of maxillary extraction site closure

Larissa **BRESSANE**[1]
https://orcid.org/0000-0002-5975-104X
Guilherme **JANSON**[1]
https://orcid.org/0000-0001-5969-5175
Rodrigo **NAVEDA**[1] ✉
https://orcid.org/0000-0001-8114-7650
Marcos Roberto de **FREITAS**[1]
https://orcid.org/0000-0002-5310-3666
Daniela **GARIB**[1,2]
https://orcid.org/0000-0002-2449-1620

Submitted: May 21, 2019 • **Revised and accepted:** November 20, 2019

✉rodrigonaveda8@gmail.com

How to cite: Bressane L, Janson G, Naveda R, Freitas MR, Garib D. Factors affecting the stability of maxillary extraction site closure. Dental Press J Orthod. 2021;26(2):e2119187.

(1) Universidade de São Paulo, Departamento de Ortodontia da Faculdade de Odontologia de Bauru (Bauru/SP, Brazil). (2) Hospital de Reabilitação de Anomalias Craniofaciais (Bauru/SP, Brazil).

ABSTRACT

Introduction: A side effect observed in cases treated with extractions is the instability of orthodontic space closure.

Objective: The aim of this study was to investigate the influence of gingival invagination, presence of third molars and facial pattern, on the stability of orthodontic space-closure in the maxillary arch.

Methods: Ninety-nine subjects (41 male and 58 female) with Class I malocclusion treated with four premolars extraction were evaluated. Extraction sites reopening and gingival invaginations were evaluated in scanned dental models in the posttreatment and 1-year posttreatment stages (mean age 16.1 years). Third molars presence was evaluated at 1-year posttreatment panoramic radiographs, and the facial pattern (SN.GoGn) was evaluated in the initial lateral headfilms. Multiple logistic regression analysis was used to estimate the influence of the aforementioned independent variables on the frequency of extraction space reopening.

Results: Space reopening was observed in 20.20% of the subjects 1-year post-debonding. Gingival invaginations were present in 25.73% of quadrants after debonding and in 22.80% 1-year post-treatment. The mean pre-treatment SN.GoGn was 35.64 degrees (SD=5.26). No significant influence was observed of the three independent variables on the instability of extraction site closure.

Conclusions: The presence of gingival invaginations, third molars and facial growth pattern do not seem to influence maxillary extraction sites reopening.

Keywords: Angle Class I malocclusion. Tooth extraction. Orthodontic space closure. Space reopening.

RESUMO

Introdução: Um efeito colateral observado nos casos tratados com extrações é a instabilidade do fechamento ortodôntico do espaço. **Objetivo:** O objetivo do presente estudo foi investigar a influência da invaginação gengival, da presença de terceiros molares e do padrão facial na estabilidade do fechamento ortodôntico dos locais de extração na arcada superior. **Métodos:** Noventa e nove indivíduos (41 homens e 58 mulheres) com má oclusão de Classe I tratados com extração de quatro pré-molares foram avaliados. A reabertura dos locais de extração e as invaginações gengivais foram avaliadas nos modelos dentários digitalizados nos estágios pós-tratamento e um ano pós-tratamento (idade média de 16,1 anos). A presença dos terceiros molares foi avaliada em radiografias panorâmicas de um ano pós-tratamento, e o padrão facial (SN.GoGn) foi avaliado nas radiografias laterais iniciais. Análise de regressão logística múltipla foi utilizada para estimar a influência das variáveis independentes citadas na frequência de reabertura do espaço de extração. **Resultados:** A reabertura do espaço foi observada em 20,20% dos sujeitos um ano após a remoção do aparelho. Invaginações gengivais estiveram presentes em 25,73% dos quadrantes após a remoção do aparelho e em 22,80% após um ano pós-tratamento. O SN.GoGn pré-tratamento médio foi de 35,64 graus (DP = 5,26). Não foi observada influência significativa das três variáveis independentes sobre a instabilidade do fechamento do local de extração. **Conclusões:** A presença de invaginações gengivais, terceiros molares e padrão de crescimento facial não parece influenciar na reabertura dos locais de extração maxilar.

Palavras-chave: Má oclusão Classe I de Angle. Extração dentária. Fechamento de espaço ortodôntico. Reabertura do espaço.

INTRODUCTION

Maintaining extraction spaces fully closed in the long-term remains a challenge for clinical Orthodontics.[1-4] Extraction space reopening determine both esthetic and functional problems, such as interproximal food impaction.[1] Approximately 30% of Class I patients presented extraction space reopening 1-year posttreatment.[5] The group with space relapse presented smaller initial dental crowding and greater amount of incisors retraction during orthodontic treatment.

Some factors such as inadequate dental interdigitation, imbalance between intraoral and extraoral forces, deficient occlusal results after orthodontic treatment, lack of proper retention protocol, distortion of the periodontal fibers, growth pattern and root parallelism have been considered to influence the stability of closed-spaces.[1,3] Nevertheless, reevaluation of closed-spaces stability has shown no correlation with some of these factors.[3,4] No previous study has evaluated the influence of gingival invagination, presence of third molar and facial growth on opening of extraction space using regression analysis.

After closure of an extraction site, excess of gingival tissue appears in a papillary form between the approximated teeth.[1] This gingival deformation, denominated gingival invagination, is not rapidly reorganized by the oral physiologic process and

appears to be associated with orthodontic space relapse in extraction areas.[1] However, the association between extraction space reopening and gingival invaginations has not been demonstrated so far.[1,3]

It has been suggested that the presence of third molars may influence the long term stability of mandibular alignment.[6] Although there is no scientific evidence of the third molars role in orthodontic retention,[7] some studies sustain that third molars may move teeth mesially in the long term.[8] Considering that there is physiologic mesial movement during third molars development, these mesial forces may possibly influence the long-term stability of extraction-site closure, maintaining the spaces closed.

One essential factor for orthodontic diagnosis and prognosis is the facial growth pattern. Several studies have demonstrated greater instability of anterior dental alignment in hyperdivergent patients.[9-11] As a dental compensation of the growth pattern, the incisors tend to develop more vertically, increasing their retroclination.[9] Considering this long-term behavior of the anterior teeth, would hiperdivergent patients present greater stability of extraction space closure? To date there are no investigations on this matter.

Considering the elevated prevalence of extraction space reopening in the first-year posttreatment,[5] the present study aims to assess whether gingival invagination, presence of maxillary third molars and facial growth pattern are associated with extraction space relapse in the maxillary arch.

MATERIAL AND METHODS

This study was approved by the Ethics in Research Committee of *Faculdade de Odontologia de Bauru, Universidade de São Paulo* (protocol 45794214.1.0000.5417). The initial sample comprised orthodontic records of over 2,000 patients treated with extractions between 1973 to 2015, that were retrospectively selected from the files of *Departamento de Ortodontia da Faculdade de Odontologia de Bauru, Universidade de São Paulo*. Considering a prevalence of extraction space reopening of 30.23% (0.302)[5] as *p*, and three independent variables as k, sample calculation used the formula 10 k/p, by Peduzzi et al.[12] The minimum number of cases to include was 99 subjects based on an alpha significance level of 0.05 and a beta of 0.2.

The inclusion criteria were: Class I malocclusion treated with four premolars extractions; first premolars extracted in the maxillary arch; permanent dentition; maximum of 21 years of age at treatment onset; absence of number dental anomalies; no history of periodontal surgery in the extraction areas; and complete and good quality dental records, including 1-year posttreatment dental models. The first 99 patients that met the inclusion criteria were selected.

The information regarding initial, final and 1-year posttreatment ages, as well as treatment time is described in Table 1.

All patients were treated by graduate students with 0.022x0.028-in fixed Edgewise appliances. Patients with severe anterior crowding required initial canine retraction. The archwire sequence for leveling and alignment was 0.015-in twist-flex or 0.016-in NiTi archwires, followed by 0.016, 0.018, 0.020, and 0.019x0.025-in stainless steel archwires. The extraction spaces were closed with *en-masse* retraction of the anterior teeth, with elastic chains on a rectangular stainless steel archwire. After the end of treatment, a modified Hawley retainer was used in the maxillary arch, and a fixed canine-to-canine archwire was bonded in the mandibular arch, as retention (Fig 1). The Hawley retainer was recommended to be used full-time for six months, followed by nights-only use for additional six months. The mandibular canine-to-canine bonded fixed retainer was recommended to be used for 3 years.

Table 1: Age distribution and treatment time

	Mean (years)	SD
Initial age	13.02	2.44
Age at the end of treatment	15.14	2.58
Age 1-year posttreatment	16.10	2.58
Treatment time	2.11	0.59

Figure 1: The modified Hawley retainer used by all patients in the sample.

Posttreatment and 1-year follow-up dental models were digitized using a 3D 3Shape R700 scanner (3Shape A/S, Copenhagen, Denmark). The following variables were evaluated using OrthoAnalyzer™ 3D software (3Shape A/S, Copenhagen, Denmark):

» Extraction space reopening: the presence/absence of interproximal contact between canines and second premolars was visually performed. Patients presented extraction space reopening when a fully closed site at the end of orthodontic treatment had lost interproximal contact at the 1-year follow-up (Fig 2), independently of the amount.

» Gingival invagination: presence of gingival invagination was considered when a clear gingival fold was present in the extraction areas on the buccal and/or lingual alveolar surface (Fig 3).

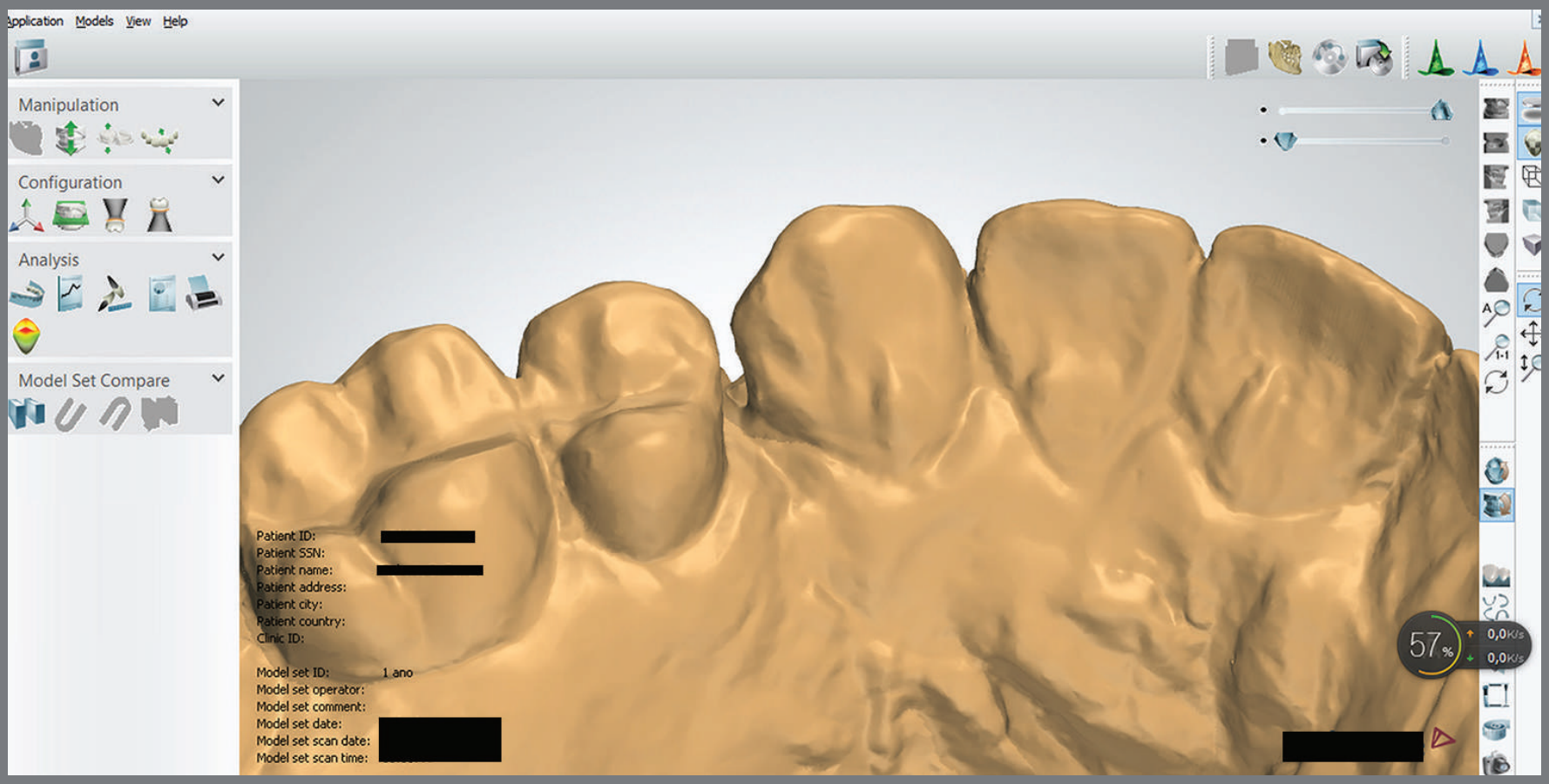


Figure 2: Visual evaluation of extraction space reopening.

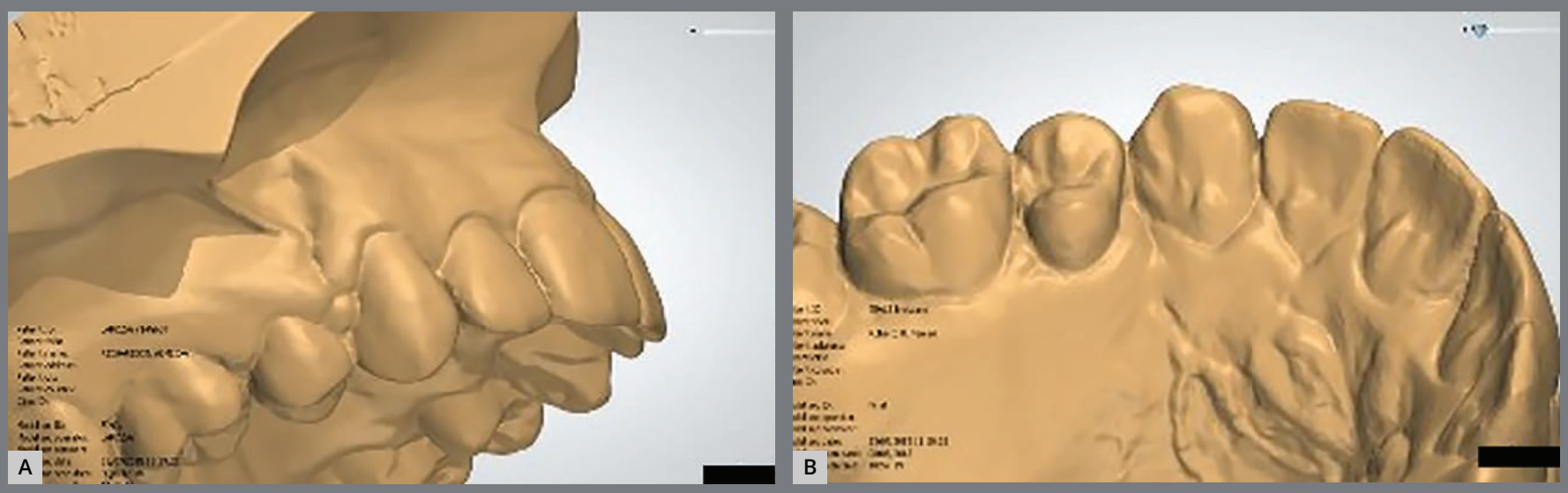


Figure 3: Visual evaluation of the presence of gingival invaginations in the extraction sites in the vestibular **(A)** and in the palatal **(B)** view.

The presence of maxillary third molars was assessed in the one year-posttreatment panoramic radiographs.

The initial cephalometric radiographs were digitized using the Microtek ScanMaker i800 scanner (Santa Fe Springs, CA, USA) and analyzed with Dolphin® 11.5 imaging software. The magnification factors were corrected. Facial growth pattern was evaluated by the SN.GoGn angle. A trained examiner evaluated all the variables.

ERROR STUDY

The quantitative variable SN.GoGn angle was re-measured in thirty randomly selected patients after a 30-day interval. Intraobserver random and systematic errors were calculated with Dahlberg's formula[13] and dependent *t*-test, respectively, at a significance level of 5%. This variable was also tested for normality using Shapiro-Wilk test.

STATISTICAL ANALYSIS

A multiple logistic regression analysis was used to estimate the influence of each factor — gingival invagination, presence of third molars and facial growth pattern — on the occurrence of extraction space reopening. The significance level was 5%. All statistical analyses were performed with Statistica software (Statistica for Windows, version 11.0, Statsoft, Tulsa, Okla).

RESULTS

The random error for the variable SN.GoGn was within acceptable limits (2.74)[14] and there was no statistically significant systematic error. The SN.GoGn angle presented normal distribution.

From the 198 maxillary spaces evaluated at the end of treatment, 171 presented fully closed spaces, and were thus considered for the regression analysis. When the variables were evaluated per quadrant, only the quadrants with fully closed spaces were taken into account. Results showed that 20 out of 99 (20.20%) of the patients demonstrated that at least one extraction site reopened after 1-year follow-up (Table 2). Extraction space reopening occurred unilaterally in 15.15% of the patients and bilaterally in 5.05%. Considering the number of quadrants in the maxillary arch that were closed at the end of treatment, 25 out of 171 (14.61%) of the closed sites reopened 1-year posttreatment.

The prevalence of gingival invaginations at the end of treatment in the sample subjects was 34.34% (34 out of 99 - Table 3). Considering the number of quadrants with fully-closed

Table 2: Prevalence of extraction space reopening at the 1-year-posttreatment stage.

Independent variable	Sample (n=99)	Per quadrant (n=171)
Space reopening	21 (21.21%)	25 (14.61%)

Table 3: Prevalence of gingival invaginations at the end of treatment and at the 1-year-post-reatment stage.

Variable	End of treatment		1-year-posttreatment
	Sample (n=99)	Per quadrant (n=171)	Per quadrant (n=44)
Gingival invaginations	34 (34.34%)	44 (25.73%)	39 (88.63%)

extraction sites, 44 out of 171 (25.73%) presented a visible gingival fold on the buccal and/or lingual alveolar surface. From the 44 sites with gingival invagination, 9 had the gingival fold both in the buccal and lingual aspects of the alveolar ridge, while 35 had the invagination only on the buccal or lingual aspects.

In the 1-year posttreament dental casts, 39 out of 44 (88.63%) of the gingival invaginations persisted in the extraction sites fully closed at the end of treatment, while 11.37% disappeared.

In the 1-year posttreatment panoramic radiographs, 90.90% of the patients had maxillary third molars present. From the 171 evaluated sites, in 154 (90.05%) the third molars were present.

In relation to the growth pattern, the mean value for the SN.GoGn angle was 35.64° (Table 4).

Results of the multiple logistic regression analysis showed no influence of the independent variables (gingival invagination, presence of third molars and growth pattern) on the frequency of extraction space reopening (Table 5).

Table 4: Distribution of SN.GoGn angle.

Variable	Mean	SD	Minimum	Maximum
SN.GoGn	35.64^0	5.26	20.60^0	50.50^0

Table 5: Multiple logistic regression analysis using the frequency of extraction space reopening as the dependent variable, and gingival invagination, presence of third molars and facial pattern as independent variables (n=171).

Independent variables	B	Standard error B	p
Gingival invagination	0.8	0.44	0.073
Presence of third molars	1.29	1.05	0.219
Facial pattern	-0.05	0.04	0.227

DISCUSSION

From the 99 subjects selected for this study, 20.20% had at least one site with space reopening in the first-year posttreatment (Table 2). Considering the number of closed maxillary quadrants at the end of treatment (171), 14.61% presented space reopening. Previous studies have also reported the high frequency of extraction space reopening,[1,5] encouraging the investigation of associated factors. Garib et al[5] recently observed a 30.23-percent prevalence of extraction space reopening one year after fixed appliance removal. Given this high incidence, the first and second years of retention after appliance removal would be essential for space closure stability.[5,15] According to Thilander et al,[16] the orthodontist must distinguish the rapid relapse, occurring during the period of remodeling of periodontal structures, from the slow relapse, which responds to late changes occurring during the postretention period. Thus, this study evaluated the “rapid relapse” of extraction-sites reopening.

Gingival invaginations were observed in 34.34% of the subjects and in 25.73% of the quadrants, at the end of treatment (Table 3). Similarly, Robertson et al,[17] whose investigation also included clinical observation and probing of extraction sites, found a 35-percent prevalence of gingival invaginations. On the other hand, Rivera Circuns and Tulloch[3] found a higher prevalence of gingival invaginations (87.5%) compared to our results. These differences may rely on the methodological differences, once the gingival papilae were probed in the study by Rivera Circuns and Tulloch,[3] and due to inclusion of the mandibular arch in the survey, where gingival invaginations are more common and severe.[3,17,18] Late closure of extraction sites may also influence the formation and severity of gingival folds.[18,19] Diedrich and Wehrbein[19] compared the frequency of gingival invaginations in recent and healed extraction sites, and their results showed that early closure of the spaces reduces the occurrence of invaginations. Thus, less deleterious effects are likely to occur on attached gingiva when orthodontic retraction is performed into fresh extraction sites. However, a more recent study showed no statistically significant differences between early and late space closure regarding the incidence and severity of gingival invaginations.[20]

There was a clear tendency for gingival invaginations to persist in the long-term posttreatment. From the 44 quadrants presenting invaginations, 88.63% remained in the one-year

follow-up, while 11.37% disappeared (Table 3). These findings are in accordance with the results by Robertson et al,[17] showing that gingival invaginations may persist for as long as five years after extraction space closure. Edwards stated that, eventually, natural oral processes might completely eliminate the excess of gingival tissue between approximated teeth.[1] The etiology of gingival invaginations seems to be related to fibers displacement instead of remodeling, and may persist for long periods after orthodontic retention.[21]

Numerous authors suggested that gingival invaginations were the main predisposing factor for extraction space reopening.[1,2,17-19,21-23] Our results, in accordance with the study by Rivera Circuns and Tulloch,[3] have not confirmed such assumption. No significant correlation was observed between gingival invagination and space reopening (Table 5). Thus, periodontal surgery for solving the invaginations in order to avoid space relapse is not substantiated.

The presence or absence of third molars were not related to space relapse/stability (Table 5). The possible explanation is that the irruption of third molars do not have enough force to produce mesial posterior teeth movement.[24,25]

The mean value for the SN.GoGn angle was 35.64°, indicating that the sample had a slight vertical growth tendency (Table 4).[26] The inclusion criteria may explain this result, once patients

treated with four-premolar extractions were selected. Premolar extractions are most often required in hyperdivergent patients, considering their reduced overbite, compared to hipodivergent patients.[27-30] Hyperdivergent patients tend to end orthodontic treatment with the mandibular incisors more vertically positioned, while hypodivergent patients have more projected mandibular incisors at the end of treatment.[29] The hypothesis that hyperdivergent patients would present greater stability of extraction space closure was rejected. No significant correlation between SN.GoGn angle, which is usually used to determine growth pattern, and extraction space reopening was found (Table 5).

Stability of extraction space closure remains uncertain, considering that most investigations that searched for associated factors did not detect significant results.[3] However, a greater amount of initial crowding and smaller anterior retraction seem to positively influence the stability of extraction space closure.[5] Therefore, treatment of biprotrusion performed with extractions, needing accentuated retractions, would demand longer retention time.

Despite the limitations of having evaluated gingival invaginations on dental casts, the results of this study should be considered when closed-spaces reopening is evaluated. Future studies should investigate closed-space reopening and the predisposing factors in Class II and Class III compensatory treatment.

CONCLUSIONS

» Maxillary extraction space reopening was observed in 21.21% of the subjects and in 14.61% of the quadrants, 1-year posttreatment.

» One third of the patients had gingival invaginations on the maxillary extraction sites at the end of treatment.

» One-year posttreatment, 88.63% of the gingival invaginations persisted.

» Gingival invaginations, presence of maxillary third molars and facial growth pattern do not seem to influence space closure stability in the maxillary arch.

AUTHORS' CONTRIBUTION

Larissa Bressane (LB)

Guilherme Janson (GJ)

Rodrigo Naveda (RN)

Marcos Roberto de Freitas (MRF)

Daniela Garib (DG)

Conception or design of the study:

LB, DG.

Data acquisition, analysis or interpretation:

LB, GJ, RN, MRF, DG.

Writing the article:

LB, GJ, RN, DG.

Critical revision of the article:

LB, GJ, RN, MRF, DG.

Final approval of the article:

LB, GJ, RN, MRF, DG.

Fundraising:

LB, DG.

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

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

REFERENCES

1. Edwards JG. The prevention of relapse in extraction cases. Am J Orthod. 1971;60:128-44.

2. Crossman IG, Reed RT. Long term results of premolar extractions in orthodontic treatment. Br J Orthod. 1978;5:61-6.

3. Rivera Circuns AL, Tulloch JF. Gingival invagination in extraction sites of orthodontic patients: their incidence, effects on periodontal health, and orthodontic treatment. Am J Orthod. 1983;83:469-76.

4. Chiqueto K, Janson G, Almeida CT, Storniolo JM, Barros SE, Henriques JF. Influence of root parallelism on the stability of extraction-site closures. Am J Orthod Dentofacial Orthop. 2011;139(6):e505-10.

5. Garib DG, Bressane LB, Janson G, Gribel BF. Stability of extraction space closure. Am J Orthod Dentofacial Orthop. 2016;149(1):24-30.

6. Bergstrom K, Jensen R. The significance of third molars in the aetiology of crowding. Trans Eur Orthod Soc. 1960;85-94.

7. Bishara SE. Third molars: a dilemma! Or is it? Am J Orthod Dentofacial Orthop. 1999;115(6):628-33.

8. Robinson RJ, Vasir NS. The great eights debate: do the mandibular third molars affect incisor crowding? A review of the literature. Dent Update. 1993;20(6):242-46.

9. Bjork A, Skieller V. Facial development and tooth eruption. An implant study at the age of puberty. Am J Orthod. 1972;62(4):339-83.

10. Nanda RS, Nanda SK. Considerations of dentofacial growth in long-term retention and stability: is active retention needed? Am J Orthod Dentofacial Orthop. 1992;101(4):297-302.

11. Goldberg AI, Behrents RG, Oliver DR, Buschang PH. Facial divergence and mandibular crowding in treated subjects. Angle Orthod. 2013;83(3):381-8.

12. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. J Clin Epidemiol. 1996;49(12):1373-9.

13. Dahlberg G. Standard error and medicine. Acta Genet. 1950;1:313-21.

14. Garib DG, Henriques JF, Carvalho PE, Gomes SC. Longitudinal effects of rapid maxillary expansion. Angle Orthod. 2007;77(3):442-8.

15. Edman Tynelius G, Bondemark L, Lilja-Karlander E. A randomized controlled trial of three orthodontic retention methods in Class I four premolar extraction cases -- stability after 2 years in retention. Orthod Craniofac Res. 2013;16(2):105-15.

16. Thilander B, Nyman S, Karring T, Magnusson I. Bone regeneration in alveolar bone dehiscences related to orthodontic tooth movements. Eur J Orthod. 1983;5(2):105-14.

17. Robertson PB, Schultz LD, Levy BM. Occurrence and distribution of interdental gingival clefts following orthodontic movement into bicuspid extraction sites. J Periodontol. 1977;48(4):232-5.

18. Reichert C, Golz L, Dirk C, Jager A. Retrospective investigation of gingival invaginations : Part I: Clinical findings and presentation of a coding system. J Orofac Orthop. 2012;73(4):307-16.

19. Diedrich P, Wehrbein H. Orthodontic retraction into recent and healed extraction sites. A histologic study. J Orofac Orthop. 1997;58(2):90-9.

20. Reichert C, Kutschera E, Plotz C, Scharf S, Golz L, Fimmers R, et al. Incidence and severity of gingival invaginations associated with early versus late initiation of orthodontic space closure after tooth extraction : A multicenter pilot and randomized controlled trial. J Orofac Orthop. 2017;78(5):415-25.

21. Atherton JD. The gingival response to orthodontic tooth movement. Am J Orthod. 1970;58(2):179-86.

22. Ronnerman A, Larsson E. Overjet, overbite, intercanine distance and root resorption in orthodontically treated patients. A ten year follow-up study. Swed Dent J. 1981;5(1):21-7.

23. Wehrbein H, Bauer W, Diedrich PR. Gingival invagination area after space closure: a histologic study. Am J Orthod Dentofacial Orthop. 1995;108(6):593-8.

24. Selmani ME, Gjorgova J, Selmani ME, Shkreta M, Duci SB. Effects of lower third molar angulation and position on lower arch crowding. Int J Orthod Milwaukee. 2016;27(1):45-9.

25. Esan T, Schepartz LA. Third molar impaction and agenesis: influence on anterior crowding. Ann Hum Biol. 2017;44(1):46-52.

26. Ahmed M, Shaikh A, Fida M. Diagnostic performance of various cephalometric parameters for the assessment of vertical growth pattern. Dental Press J Orthod. 2016;21(4):41-49.

27. Klapper L, Navarro SF, Bowman D, Pawlowski B. The influence of extraction and nonextraction orthodontic treatment on brachyfacial and dolichofacial growth patterns. Am J Orthod Dentofacial Orthop. 1992;101(5):425-30.

28. Tweed CH. Indications for the extraction of teeth in orthodontic procedure. Am J Orthod Oral Surg. 1944;42:22-45.

29. Tweed CH. The Frankfort-mandibular plane angle in orthodontic diagnosis, classification, treatment planning, and prognosis. Am J Orthod Oral Surg. 1946;32:175-230.

30. Proffit WR. Forty-year review of extraction frequencies at a university orthodontic clinic. Angle Orthod. 1994;64(6):407-14.

Dental Press Journal of
ORTHODONTICS

Volume 26 - Number 2 - Online

ORIGINAL ARTICLE

https://doi.org/10.1590/2177-6709.26.2.e2119199.oar

The influence of elastomeric ligatures pigmentation on smile aesthetics during orthodontic treatment

Amanda Galindo Florêncio **MIRANDA**[1]
https://orcid.org/0000-0002-2736-2461
Ana Paula Terossi de **GODOI**[2]
https://orcid.org/0000-0003-4631-2563
Carolina Carmo de **MENEZES**[2]
https://orcid.org/0000-0002-8875-8611
Mário **VEDOVELLO FILHO**[2]
https://orcid.org/0000-0002-5944-7937
Giovana Cherubini **VENEZIAN**[2] ✉
https://orcid.org/0000-0003-4643-7964

Submitted: June 11, 2019 • **Revised and accepted:** November 20, 2019

✉ giovanavenezian@hotmail.com

How to cite: Miranda AGF, Godoi APT, Menezes CC, Vedovello Filho M, Venezian GC. The influence of elastomeric ligatures pigmentation on smile aesthetics during orthodontic treatment. Dental Press J Orthod. 2021;26(2):e2119199.

(1) Universidade Maurício de Nassau, Departamento de Odontologia (Caruaru/PE, Brazil). (2) Centro Universitário da Fundação Hermínio Ometto, Departamento de Odontologia (Araras/SP, Brazil).

ABSTRACT

Aim: To assess the influence of elastomeric ligatures, subjected to a previous *in vitro* pigmentation process using different substances, on smile aesthetics during orthodontic treatment, from the perception of students and professionals.

Methods: Eight elastomeric ligatures of five commercial brands (3M/Unitek, American Orthodontics, Morelli, Ortho Technology, and Orthometric) (n=8) were immersed in coffee, Coca-Cola, and red wine for one minute per day, for 28 days; and another group of ligatures was immersed in artificial saliva. All samples were photographed and subsequently analyzed using the Adobe Photoshop software, by the RGB method. Afterwards, the pigmented ligatures were inserted in a patient wearing orthodontic brackets, and zoomed photographs of the smile were taken and presented to 40 evaluators, who filled in a satisfaction scale sheet to express their opinion on the smile aesthetics of each photograph. The color data were subjected to analysis of variance (ANOVA) and Tukey tests.

Results: The substance with the highest pigmentation potential was coffee ($p < 0.05$) followed by red wine ($p < 0.05$). Comparison among the brands used in this study showed that American Orthodontics and Orthometric had the lowest degree of pigmentation when immersed in coffee and red wine ($p < 0.05$), respectively. However, the brand that showed the highest level of satisfaction among the evaluators was Ortho Technology.

Conclusions: The presence of pigmented elastomeric ligatures affected smile aesthetics, when compared with the control group.

Keywords: Orthodontic brackets. Elastomeric ligatures. Dental aesthetic.

RESUMO

Objetivo: Avaliar a influência das ligaduras elásticas submetidas a um processo prévio de pigmentação *in vitro*, com diferentes substâncias, na estética do sorriso durante o tratamento ortodôntico, segundo a percepção de alunos e profissionais.

Métodos: Oito ligaduras elásticas de cinco marcas comerciais (3M Unitek, American Orthodontics, Morelli, Ortho Technology e Orthometric) (n = 8) foram imersas em café, Coca-Cola e vinho tinto por um minuto por dia, por 28 dias, e outro grupo de ligaduras foi imerso em saliva artificial. Todas as amostras foram fotografadas e posteriormente analisadas no *software* Adobe Photoshop, pelo método RGB. Em seguida, as ligaduras pigmentadas foram inseridas em um paciente com braquetes ortodônticos, e fotografias ampliadas do sorriso foram tiradas e apresentadas a 40 avaliadores, que preencheram uma escala de satisfação para representar sua opinião sobre a estética do sorriso de cada fotografia. Os dados de cor foram submetidos à análise de variância (ANOVA) e testes de Tukey.

Resultados: A substância com maior potencial de pigmentação foi o café ($p < 0,05$), seguido do vinho tinto ($p < 0,05$). A comparação entre as marcas utilizadas nesse estudo mostrou que a American Orthodontics e a Orthometric apresentaram o menor grau de pigmentação quando imersas em café e vinho tinto ($p < 0,05$), respectivamente. Porém, a marca que apresentou maior nível de satisfação entre os avaliadores foi a Ortho Technology.

Conclusões: A presença de ligaduras elásticas pigmentadas afetou a estética do sorriso, quando comparada à do grupo controle.

Palavras-chave: Braquetes ortodônticos. Ligaduras elásticas. Estética dentária.

INTRODUCTION

The increasing aesthetics concern has become an important issue into fixed orthodontic appliances, and has established it as a goal for orthodontists to achieve,[1] especially during orthodontic treatment of adult patients.[2,3] To meet the aesthetic expectations of more demanding patients during orthodontic treatment, aesthetic orthodontic appliances have been designed with the aim of filling this gap in the specialty.[4] When offering these options to patients, orthodontists should use not only ceramic brackets, but accessories that also benefit this type of appliance, such as aesthetic elastic archwires and ligatures.[5]

The perception of the extent to which the ligature will harm smile aesthetics has a direct effect on the commercial brand selected by the orthodontist.[6] Several studies[6-12] have been conducted with the purpose of indicating to orthodontists the types of ligatures that have the lowest influence on aesthetics. However, the method used by the majority of studies analyzed was limited to laboratory tests,[6-10] and overlooked the most important factor when assessing aesthetics; that is subjectivity, or evaluating only aesthetic perception without standardizing and assessing the degree of elastic pigmentation,[13] making it impossible to identify the substances that most affect aesthetics. Therefore, further studies on pigmentation of elastomeric ligatures might be helpful in contributing to the improvement

of these materials.[3] In addition, this is relevant for professionals, as this will allow them to prioritize the use of materials with better characteristics and enable them to offer their patients guidance with regard to their diets. In this context, the present study aimed to assess the influence of aesthetic ligatures of five commercial brands on smile aesthetics during orthodontic treatment, from the perception of students and specialists. The ligatures were subjected to an *in vitro* pigmentation process with four solutions. This study tested the hypothesis that pigmentation of elastomeric ligatures would affect smile aesthetics and that there would be differences among the commercial brands and solutions tested.

MATERIAL AND METHODS

The Ethics Committee of University Center of Hermínio Ometto Foundation (FHO) approved this study (number 2.125.443).

SAMPLE SIZING

The sample calculation performed for the color stability analysis indicated that there was very low variability of samples among the elastomeric ligatures, thus providing a low coefficient of variation of 0.28% for the experiment. Therefore, the sample size of eight ligatures per group, resulting in 160 ligatures, provided a high degree of freedom in the residue analysis (DF=140), with test power higher than 0.99 for the main effects of brand and solution, and for the interaction between them.

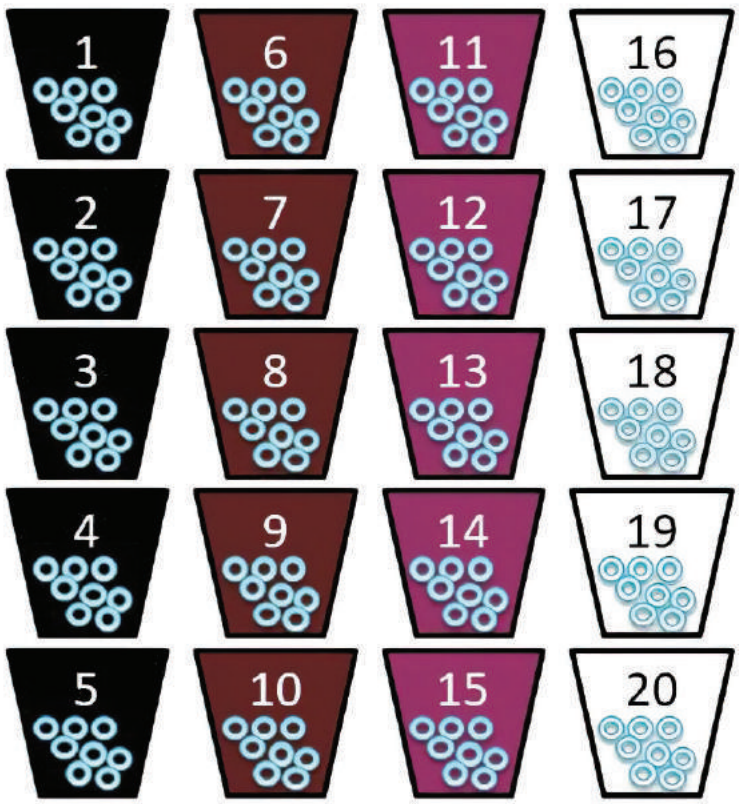
For the aesthetic perception analysis, the sample of this study was calculated based on data from a previous study,[6] which indicated coefficient of variation of 22.8% and sample size of 20 students and 20 orthodontists, resulting in 40 evaluators. This sample size resulted in a test power higher than 0.99 for the main effects of evaluator (student or orthodontist), brand, solution, and double or triple interactions.

COLOR STABILITY ANALYSIS

Different commercial brands of aesthetic elastomeric ligatures were selected: 3M/Unitek (Monrovia, California, USA) - pearl, American Orthodontics (Sheboygan, Wisconsin, USA) - pearl, Morelli (Sorocaba, São Paulo, Brazil) - clear, Ortho Technology (Lutz, Florida, USA) - clear, and Orthometric (Marília, São Paulo, Brazil) - clear. Each group included eight ligatures (n=8) divided according to the five commercial brands and four solutions used for immersion, resulting in 160 ligatures.

The *in vitro* pigmentation process was performed using the following four different potential solutions: coffee (Melitta, Minden, Louisiana, USA), Coca-Cola (Atlanta, Georgia, USA), red wine (Quinta do Morgado, Flores da Cunha, Rio Grande do Sul, Brazil) and artificial saliva (Saliform, Iasi, Romania).

The ligatures were immersed for one minute per day in 40 ml of each solution to simulate the *in vivo* contact[14] (Fig 1). After one minute, the specimens were inserted in containers containing artificial saliva, with one container for each group. These containers were wrapped in PVC plastic film and stored in an incubator



SPECIMENS

GROUP 1
Commercial brand: 3M Unitek
Immersion solution: soft drink
GROUP 2
Commercial brand: American Orthodontics
Immersion solution: soft drink
GROUP 3
Commercial brand: Morelli
Immersion solution: soft drink
GROUP 4
Commercial brand: Ortho Technology
Immersion solution: soft drink
GROUP 5
Commercial brand: Orthometric
Immersion solution: soft drink
GROUP 6
Commercial brand: 3M Unitek
Immersion solution: coffee
GROUP 7
Commercial brand: American Orthodontics
Immersion solution: coffee
GROUP 8
Commercial brand: Morelli
Immersion solution: coffee
GROUP 9
Commercial brand: Ortho Technology
Immersion solution: coffee
GROUP 10
Commercial brand: Orthometric
Immersion solution: coffee
GROUP 11
Commercial brand: 3M Unitek
Immersion solution: red wine
GROUP 12
Commercial brand: American Orthodontics
Immersion solution: red wine
GROUP 13
Commercial brand: Morelli
Immersion solution: red wine
GROUP 14
Commercial brand: Ortho Technology
Immersion solution: red wine
GROUP 15
Commercial brand: Orthometric
Immersion solution: red wine
GROUP 16
Commercial brand: 3M Unitek
Immersion solution: artificial saliva
GROUP 17
Commercial brand: American Orthodontics
Immersion solution: artificial saliva
GROUP 18
Commercial brand: Morelli
Immersion solution: artificial saliva
GROUP 19
Commercial brand: Ortho Technology
Immersion solution: artificial saliva
GROUP 20
Commercial brand: Orthometric
Immersion solution: artificial saliva

Figure 1: A sketch illustrating the specimens in each plastic receptacle identified by the number of the group, and the text on the right explaining both the commercial brand and the substance of immersion used in each group.

at 37°C, to reproduce the intraoral temperature. The immersion solutions used were renewed every day. The specimens were photographed after 28 days, because the mean time interval between visits and consequent ligature replacement *in vivo* is known to be approximately 28 days.[1,6-13,15,16]

A digital camera (Canon EOS 70D model, Canon, Tokyo, Japan) with resolution of 20.2 megapixels, 16-bit compression, and 100-mm F-10 Canon lens was used to take the photographs. The camera was set at shutter speed of 1/50 seconds, diaphragm opening of 10, ISO 200, no flashlight, true color profile, and color temperature of 5000 K, with image captured in the RAW format and converted to the TIFF format.

This camera was attached to a support perpendicular to the object, at a distance of 31 centimeters above, in an environment free of natural and/or artificial light. The specimens were placed on a light table that was turned on and was the only light source in the room.[7] A photograph was taken of all ligatures of each group after the in vitro pigmentation process, resulting in 160 photographs.

The images were transferred to the computer and converted to the TIFF format. Afterwards all the images were analyzed using the Adobe Photoshop CC 2017™ software (Adobe Systems Incorporated, San Jose, California, USA), in which a 100% zoom was applied for image visualization.[7]

The colors presented in the image were analyzed through levels of brightness (B), red (R), green (G), blue (B), and the sum of colors (RGB method). The color measured with the RGB method is aided by values in a scale ranging from 0 to 255, which provides the precise shade of a certain color. The closer the value was to 0, the darker would be the image. Similarly, the closer the value was to 255, the lighter would be the image (Fig 2), according to a previously published method.[7,9]

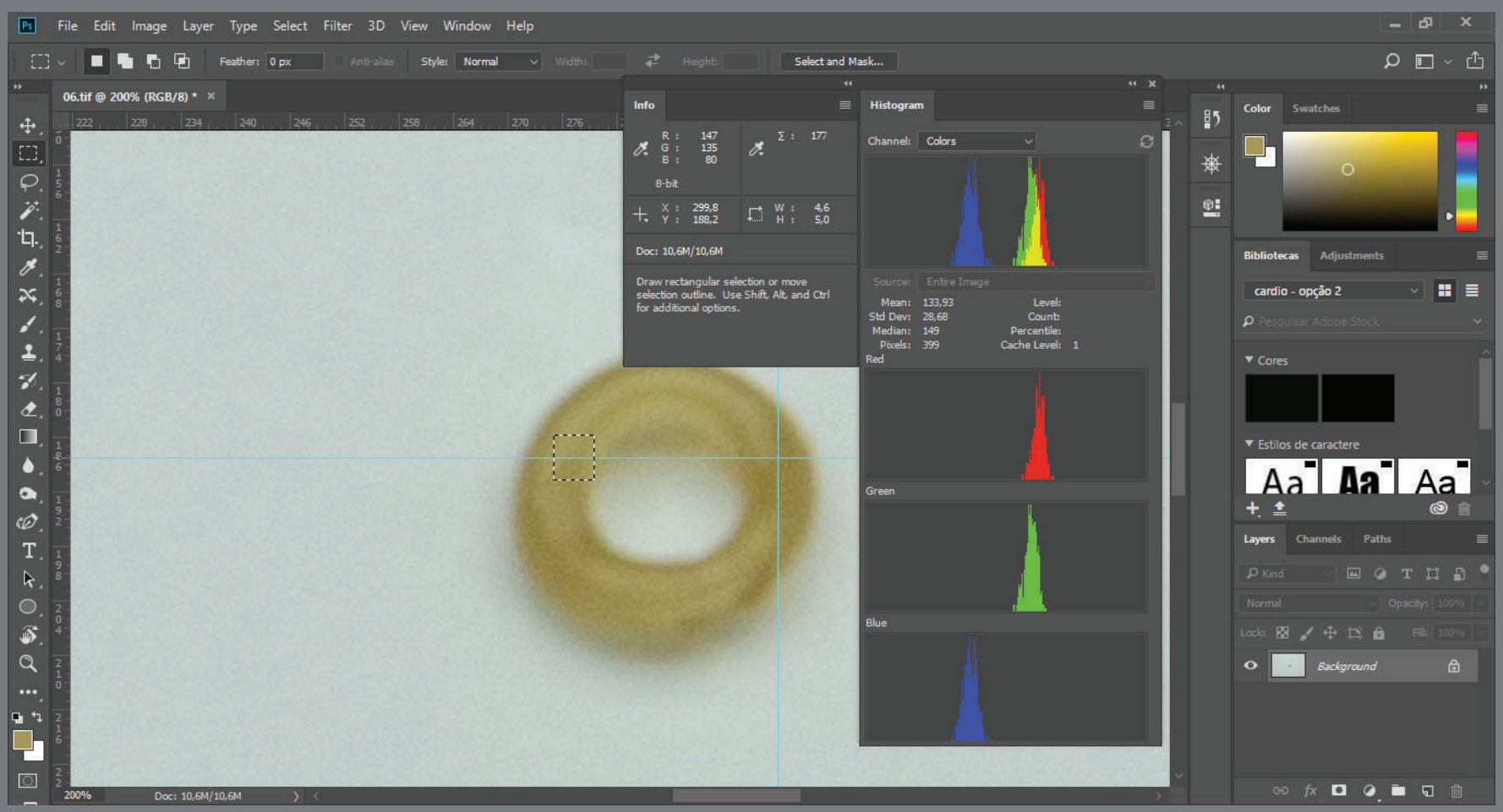


Figure 2: Image of color analysis of specimens in the Adobe Photoshop CC 2017®. The parameters of analyses by the RGB model are shown on the left side of the image.

AESTHETIC PERCEPTION ANALYSIS

A patient wearing an aesthetic fixed orthodontic appliance with ceramic brackets from the Abzil brand, Transcend model, Roth prescription, 0.022-in slot, was selected as a model for the present study. The stages of dental alignment and leveling were concluded. All ligatures used in the first laboratory phase of this study were tied to the brackets already placed in the patient, using Mathieu tweezers. Photographs were taken of the patient's smile in a constant position in all shots. To standardize the photographs, the patient was seated with Frankfurt and bipupilar planes parallel to the ground, the head was positioned with the help of head positioners and a cephalostat was placed on each side, to decrease movement as much as possible. The patient was instructed to keep smiling during the photographic shots. To prevent distortion of the images, the positioners were placed perpendicular to the camera lens, so that both right and left sides of the patient were at the same distance from the camera lens, following the method used by Ferraz et al.[6] The same camera used in the laboratory phase was applied in the second phase, using a macro lens of 105 mm, with circular flashlight, and set at shutter speed of 1/50 seconds, with diaphragm opening of 8, true color profile, and color temperature of 5200 K. The camera was attached to a support perpendicular to the object, at

a distance of 35 centimeters from the patient, using the ratio of 1:2.8 from the objective, to obtain a close-up photograph of the smile. Twenty photographs were taken, including the ligatures previously photographed in the laboratory phase. They were captured in the RAW format, transferred to and filed in a computer, in which they were converted to JPEG, printed at 2x magnification on 10x15 mm photographic paper, and identified with numbers from 1 to 20 (Fig 3).

A semi-structured questionnaire was prepared with 20 nominal satisfaction scales, with grades from 1 to 5, to determine the evaluator's level of satisfaction with the smile aesthetics shown in each photograph, following the method proposed by Ferraz et al.[6] Grade 1 corresponded to "very poor", 2 was "poor", 3 was "regular", 4 was "good", and 5 was "very good", and the evaluators had to select the option most representative of their satisfaction.

Figure 3: Photographs of the smile: (**A)** without pigmentation and (**B)** with pigmentation.

For esthetic evaluation of the smile, all the photographs were judged by 40 evaluators (20 orthodontists and 20 dental students). The orthodontists aged between 27 and 51 years (mean of 37.15 years), with time since postgraduation ranging between 3 and 17 years (mean of 7.35 years). The professionals were randomly selected from a list of orthodontists registered at a Center of Post-Graduation in Dentistry (Random number calculators of the GraphPad Prism software program).

The other evaluators were students in the first year of dental school, aged between 18 and 35 years (mean of 24.55 years), randomly selected (Random number calculators of the GraphPad Prism software program). Students who had performed technical courses in the field of Dentistry were not included in the study. The selected students did not have the technical-scientific knowledge of an orthodontist and for the purpose of the present study they were considered lay persons.

STATISTICAL ANALYSIS

After the descriptive and exploratory analysis, the color data (RGB model) were subjected to analysis of variance (ANOVA) in a 5x4 factorial scheme (brand x solution) and to the Tukey test. Data on the level of satisfaction were analyzed using generalized linear models by the PROC GENMOD procedure of the SAS software, considering the factors of brand, solution, and the interaction between them. All analyses considered a 5% level of significance.

RESULTS

Table 1 shows that when immersed in artificial saliva (control group), the Orthometric ligatures showed the lightest color (226.00 ± 0.53), followed by the brands Morelli (214.38 ± 0.52), American Orthodontics (206.88 ± 0.35), Ortho Technology (204.00 ± 0.53), and lastly (the darkest ligatures) 3M/Unitek (192.63 ± 0.74), with statistical difference among all of them ($p < 0.05$).

Immersion in Coca-Cola showed a significant increase in pigmentation in all the groups, when compared with the control group ($p \leq 0.05$), except for American Orthodontics ligatures (207.88 ± 0.35) ($p > 0.05$). The lightest ligatures were those of American Orthodontics (207.88 ± 0.35) and Orthometric (207.88 ± 0.64) that showed no statistically significant difference between them ($p > 0.05$). The darkest ligatures were those of Morelli (178.38 ± 1.06) ($p < 0.05$), which differed from all the other ligature brands.

When immersed in coffee, all brands also showed significantly lower mean pigmentation values than the control group ($p < 0.05$), indicating that there was a significant increase in pigmentation. Furthermore, American Orthodontics ligatures (202.88 ± 0.35) were the lightest ($p < 0.05$), while the 3M/Unitek ligatures (136.88 ± 0.35) were the darkest ($p < 0.05$).

Table 1: Mean color values (RGB method), mean (standard deviation), for both commercial brands and solution.

Commercial brand	Solution			
	Coke	Coffee	Red wine	Control group
3M Unitek	188.00 (0.53)^{Bc}	136.88 (0.35)^{Ce}	118.25 (0.46)^{De}	192.63 (0.74)^{Ae}
American Orthodontics	207.88 (0.35)^{Aa}	202.88 (0.35)^{Ba}	185.13 (0.35)^{Cb}	206.88 (0.35)^{Ac}
Morelli	178.38 (1.06)^{Bd}	154.75 (0.46)^{Dd}	158.00 (0.53)^{Cd}	214.38 (0.52)^{Ab}
Orto Technology	191.13 (0.35)^{Bb}	163.00 (0.00)^{Dc}	176.88 (0.35)^{Cc}	204.00 (0.53)^{Ad}
Orthometric	207.88 (0.64)^{Ba}	194.13 (0.35)^{Db}	196.63 (0.52)^{Ca}	226.00 (0.53)^{Aa}

Means followed by different letters (capital letters on the horizontal and lower case letters on the vertical) diverge among themselves (≤ 0.05).

For the wine immersion solution, all brands also showed difference in color of one shade darker than the control group (p <0.05). Orthometric ligatures (196.63 ± 0.52) were the lightest (p < 0.05) and 3M/Unitek (118.25 ± 0.46) ligatures were the darkest (p < 0.05).

Figure 4 and Table 2 shows the results of the analysis on the level of satisfaction of orthodontists and university students with smile aesthetics. Both orthodontists and students showed a higher level of satisfaction with the photographs with ligatures immersed in artificial saliva (control group) and Coca-Cola, without differences between them (p > 0.05).

For Morelli, 3M/Unitek, and Ortho Technology, the level of satisfaction with the ligatures immersed in wine was lower, and even lower with those immersed in coffee ($p < 0.05$). American Orthodontics and Ortho Technology showed significant difference in satisfaction of both orthodontists and students only with coffee ($p < 0.05$).

For the ligatures immersed in Coca-Cola, a higher level of satisfaction by both orthodontists and students was perceived with the Orthometric (median = 5) than with the Ortho Technology ligatures (median = 4) ($p < 0.05$).

Table 2: Median (minimum value; maximum value) of the evaluator's level of satisfaction with the aesthetics of the smile according to the brand of elastomeric ligatures and the solution.

Evaluators	Brands	Solution			
		Coke	Coffee	Red wine	Control Group
Orthodontists	3M	*5.0 (4.0; 5.0)^{Aab}	1.0 (1.0; 2.0)^{Cb}	*3.0 (2.0; 4.0)^{Bc}	4.0 (3.0; 5.0)^{Aa}
	American Orthodontics	4.0 (3.0; 5.0)^{Aab}	1.0 (1.0; 2.0)^{Cb}	*4.0 (3.0; 5.0)^{Bab}	4.0 (2.0; 5.0)^{ABa}
	Morelli	*5.0 (4.0; 5.0)^{Aab}	1.0 (1.0; 2.0)^{Cb}	*4.0 (2.0; 5.0)^{Bab}	5.0 (2.0; 5.0)^{Aa}
	Orto Technology	4.0 (2.0; 5.0)^{Ab}	2.0 (1.0; 4.0)^{Ba}	4.0 (3.0; 5.0)^{Aa}	4.0 (2.0; 5.0)^{Aa}
	Orthometric	5.0 (3.0; 5.0) ^{Aa}	1.0 (1.0; 2.0)^{Cb}	3.0 (1.0; 4.0)^{Bb}	5.0 (3.0; 5.0)^{Aa}
University students	3M	4.0 (3.0; 5.0)^{Aab}	1.0 (1.0; 4.0)^{Cb}	3.0 (1.0; 3.0)^{Bc}	4.0 (2.0; 5.0)^{Aa}
	American Orthodontics	4.0 (2.0; 5.0)^{Aab}	1.0 (1.0; 3.0)^{Cb}	3.0 (2.0; 5.0) ^{Bab}	4.0 (2.0; 5.0)^{ABa}
	Morelli	4.5 (3.0; 5.0)^{Aab}	1.0 (1.0; 3.0)^{Cb}	3.0 (2.0; 5.0) ^{Bab}	5.0 (3.0; 5.0)^{Aa}
	Orto Technology	4.0 (2.0; 5.0)^{Ab}	2.0 (1.0; 3.0)^{Ba}	4.0 (3.0; 5.0)^{Aa}	4.0 (2.0; 5.0)^{Aa}
	Orthometric	4.5 (3.0; 5.0)^{Aa}	1.0 (1.0; 4.0)^{Cb}	3.5 (1.0; 5.0)^{Bb}	4.0 (4.0; 5.0)^{Aa}

*Significant differences among evaluators, under the same brand and solution conditions ($p \leq 0.05$). Medians followed by distinct letters (upper case comparing horizontally and lower case, vertically, compares brands within each solution and evaluator) differ ($p \leq 0.05$).

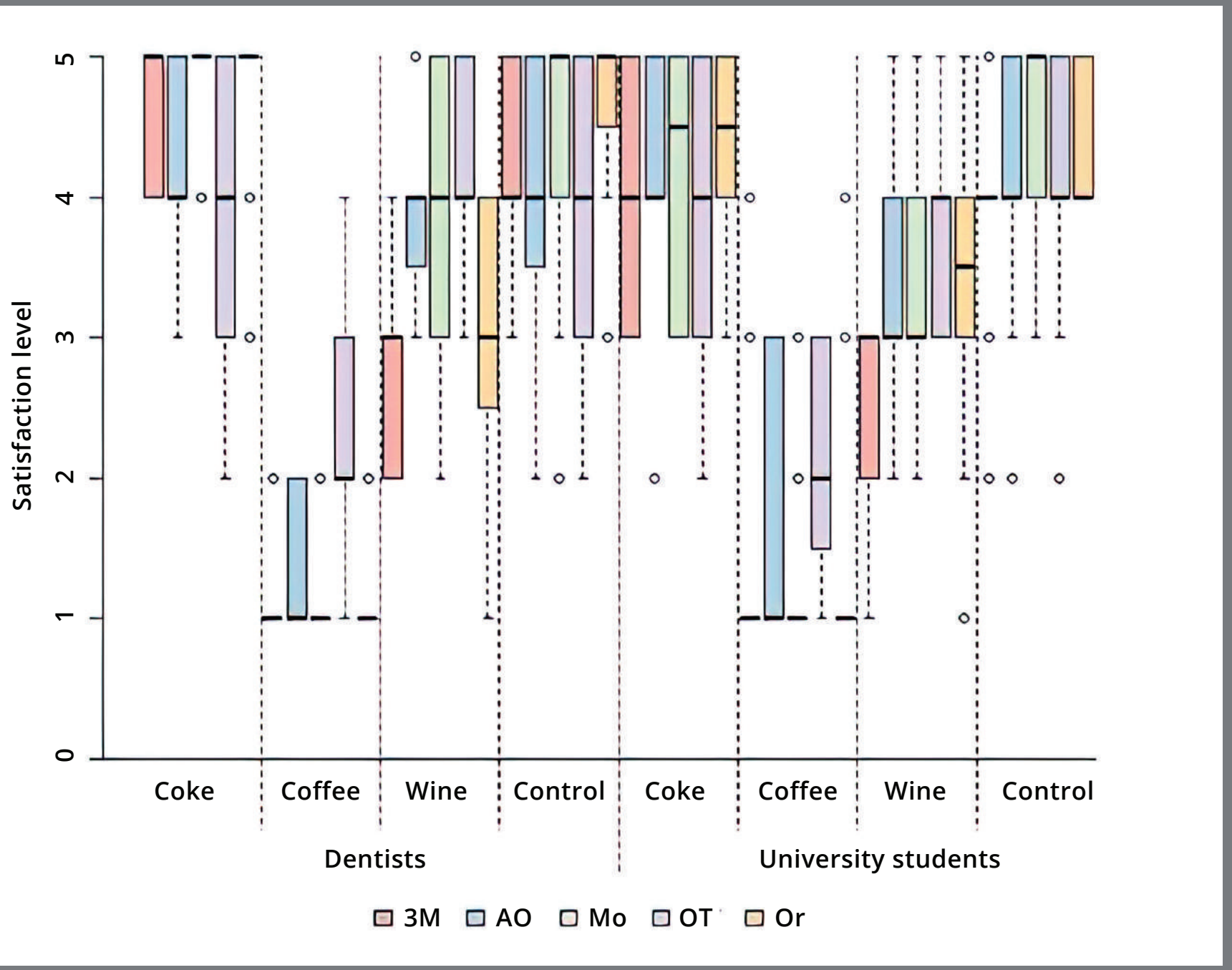


Figure 4: The box plot of the evaluator's level of satisfaction with smile aesthetics relative to elastomeric ligatures of different commercial brands and the submersion solutions. Commercial brands: 3M/Unitek; AO (American Orthodontics); Mo (Morelli); OT (Ortho Technology); Or (Orthometric).

When immersed in coffee, all brands presented the worst level of satisfaction (median = 1) ($p > 0.05$) except for Ortho Technology ligatures (median = 2; poor) ($p < 0.05$). No difference between the evaluators ($p > 0.05$) was found.

When immersed in wine, orthodontists showed higher satisfaction with the brands Ortho Technology, American Orthodontics, and Morelli (median = 4) than with Orthometric and 3M/Unitek (median = 3) ($p < 0.05$). For students, only Ortho Technology showed the highest level of satisfaction (median = 4).

In the majority of cases no significant difference was shown between orthodontists and students regarding level of satisfaction ($p > 0.05$). When a difference was found, the satisfaction of orthodontists reached higher values than the level of satisfaction of students ($p < 0.05$); this occurred for the brands 3M/Unitek and Morelli immersed in Coca-Cola and 3M/Unitek, American Orthodontics, and Morelli immersed in wine.

DISCUSSION

The aesthetic importance of the smile has been extensively discussed in the literature.[2,17-19] Orthodontics, a dental specialty that works directly with smile aesthetics, requires continuous updating of its material collection to keep up with the demands of the overall population.[4,5,20-24]

Therefore, testing the color change of elastomeric ligatures is required to guide orthodontists seeking to respect the decision of patients desiring an aesthetic smile even during orthodontic treatment. Therefore, several studies have been conducted[1,6-13,15,16] with the aim of explaining which of the aesthetic elastomeric ligatures have the least effect on smile aesthetics.

In this context, *in vitro* studies that aim to simulate *in vivo* conditions controlled by laboratory researchers[14] may be used to guide the clinical behavior. The laboratory studies conducted on the topic[1,6-12,15,16] have immersed the specimens without establishing a time that would simulate the actual situation, ranging from 3 to 30 consecutive days of immersion. In order to simulate *in vivo* conditions more accurately, the present study determined that specimens would be immersed for only one minute per day, which is closer to the time individuals would be in contact with these solutions on a daily consumption basis.[14] Moreover, in the literature consulted, few studies assessed such aesthetic perception.[1,6,13] These studies did not include a laboratory stage,[13] or did not measure color in the laboratory stage; the immersion solutions were mixed,[1,6] and studies did not compare objective and subjective results, thus further studies with methodological variations are required for better explanation of the topic.

The literature also shows divergence regarding color analysis using a spectrophotometer[8,10,15,16] and the Adobe Photoshop software.[7,9] In the present study, analysis was performed with the Adobe Photoshop software due to its practicality and efficiency, as shown in previous studies.[7,9]

The laboratory results corroborated the findings of other studies,[6,7,9,10,12,13] highlighting American Orthodontics ligatures as the most resistant to pigmentation when compared with the other brands analyzed, which suggested an association with the fabrication process. Other studies[1,11,16] have indicated other brands such as GAC, Ormco, Orthodontic Supply, and TP Orthodontics as being the most aesthetic, but they did not use American Orthodontics ligatures, which prevents comparison with this brand.

As regards the brand of aesthetic elastomeric ligatures with the highest pigmentation values in the laboratory phase, the results found in the present study were similar to those of previous studies,[1,6,9,16] indicating 3M/Unitek as the group of ligatures most susceptible to pigmentation when compared with the other brands analyzed. This may suggest that a higher level of pigmentation may be related to the fabrication process and even to a higher surface roughness of the ligature, so that further studies are required to analyze the fabrication process of the ligatures.

The subjective aesthetic perception using the satisfaction scale showed a consensus between the two groups of examiners, indicating Morelli as the least aesthetic brand and coffee as the solution with a higher pigmenting potential, which has been associated with the yellow pigment in its composition.[26]

However, Ortho Technology was the most aesthetic brand, in disagreement with all the laboratory results and confirming that aesthetics is in fact a subjective issue. Other studies have also found different results. Ferraz et al.[6] indicated American Orthodontics and Morelli ligatures as being the most aesthetic and 3M/Unitek, Ortho Technology, and TP Orthodontics as the least aesthetic types. Talic and Almundhi[1] corroborated the findings, also indicating 3M/Unitek, but they disagreed with the most aesthetic results, highlighting the Ormco brand. The study of Kawabata et al.[13] confirmed Morelli as being the least aesthetic brand and 3M/Unitek, American Orthodontics, and GAC as the most aesthetic brands. This divergence of results may be associated with different methods, such as immersion time of the ligature in the pigmenting solution. In this study, orthodontists showed higher levels of satisfaction than students. Their clinical orthodontic experience and knowledge about the inevitable pigmentation of aesthetic ligatures are suggested to be factors that may have led to a more tolerant behavior relative to aesthetic perception by the orthodontists.

The limitations highlighted in the present study are the non-differentiation between pearl and clear ligatures and the absence of pre-stretching before the pigmentation process, because evidence has shown that stretching the elastomers might affect the absorption of pigmenting agents.[9] The authors suggest that further studies should be conducted,

dissociating the types of ligatures and previous stretching in distinct groups. Also worth noting is that the elasticity degradation index was not tested in this study, requiring further studies comparing the data on color change with elasticity degradation, considering that the most aesthetic ligature is not necessarily the most effective one.

CONCLUSIONS

Smile aesthetics was found to be affected by the presence of pigmented elastomeric ligatures. American Orthodontics and Orthometric elastomeric ligatures showed the lowest *in vitro* pigmentation levels when compared with the control group. The solution with the highest pigmenting potential was coffee.

Ortho Technology was found to be the brand of ligatures most favored by both groups of evaluators (orthodontists and students).

AUTHORS' CONTRIBUTION

Amanda G. F. Miranda (AGFM)

Ana Paula Terossi de Godoi (APTG)

Carolina Carmo de Menezes (CCM)

Mário Vedovello Filho (MVF)

Giovana Cherubini Venezian (GCV)

Conception or design of the study:

AGFM.

Data acquisition, analysis or interpretation:

AGFM, APTG, CCM, MVF, GCV.

Writing the article:

AGFM, APTG, GCV.

Critical revision of the article:

AGFM, APTG, CCM, MVF, GCV.

Final approval of the article:

AGFM, APTG, CCM, MVF, GCV.

Fundraising:

MVF.

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

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

REFERENCES

1. Talic NF, Almundhi AA. The effect of dietary pigmentation on the esthetic appearance of clear orthodontic elastomeric modules. J Orthod Sci. 2016;5(2):70-3.

2. Försch M, Krull L, Hechtner M, Rahimi R, Wriedt S, Wehrbein H, et al. Perception of esthetic orthodontic appliances: an eye tracking and cross-sectional study. Angle Orthod. 2020 Jan;90(1):109-17.

3. Silva VD, Dias C, Osório LB, Baccarin Matje PR, Menezes LM, Lima EMS. Color changes of esthetic elastomeric ligatures evaluated with the Commission Internationale d'Éclairage color system. Eur J Dent. 2018 Jul-Sep;12(3):428-33.

4. Lopes Filho H, Maia LH, Araújo MV, Elias CN, Ruellas AC. Colour stability of aesthetic brackets: ceramic and plastic. Aust Orthod J. 2013;29(1):13-20.

5. Mujawar T, Agrawal M, Agrawal J, Nanjannawar L, Fulari S, Kagi V, et al. Evaluation and comparison of color stability of recent esthetic archwires: an in vitro study under spectrophotometer. Int J Sci Study. 2017;4(12):151-4.

6. Ferraz C, Castellucci M, Sobral M. Influence of in vitro pigmenting of esthetic orthodontic ligatures on smile attractiveness. Dent Press J Orthod. 2012;17(5):123-30.

7. Kim SH, Lee YK. Measurement of discolouration of orthodontic elastomeric modules with a digital camera. Eur J Orthod. 2009;31(5):556-62.

8. Fernandes ABN, Ribeiro AA, Araújo MVA, Ruellas ACO. Influence of exogenous pigmentation on the optical properties of orthodontic elastic ligatures. J Appl Oral Sci. 2011;20(4):462-6.

9. Cavalcante JS, Castellucci E, Barbosa M, Sobral MC. Evaluation of the susceptibility to pigmentation of orthodontic esthetic elastomeric ligatures. Dental Press J Orthod. 2013;18(2):20.e1-8.

10. Soldati DC, Silva RC, Oliveira AS, Kaizer MR, Moraes RR. Color stability of five orthodontic clear elastic ligatures. Orthodontics. 2013;14(1):e60-5.

11. Silva LK, Guignone BC, Marinho KC, Goiato MC, Pithon MM, Soares RV, et al. In vitro evaluation of color changes of aesthetic orthodontic elastic ligatures. Int J Odontostomatol. 2014;8(3):399-403.

12. Fernandes ABN, Ruellas ACO, Araújo MVA, Sant'anna EF, Elias CN. Assessment of exogenous pigmentation in colourless elastic ligatures. J Orthod. 2014;41(2):147-51.

13. Kawabata E, Dantas VL, Kato CB, Normando D. Color changes of esthetic orthodontic ligatures evaluated by orthodontists and patients: a clinical study. Dental Press J Orthod. 2016;21(5):53-7.

14. Godoi APT, Freitas DB, Traught KGS, Colucci V, Catirse ABCEB. Combined effect of the association between chlorhexidine and a diet protein on color stability of resin composites. Int J Clin Dent. 2011;4(2):1-9.

15. Ardeshna AP, Vaidyanathan TK. Colour changes of ortodontic elastomeric module materials exposed to in vitro dietary media. J Orthod. 2009;36(3):177-85.

16. Aldrees AM, Al-Foraidi AS, Murayshed MS, Almoammar KA. Color stability and force decay of clear orthodontic elastomeric chains: an in vitro study. Int Orthod. 2015;13(3):287-301.

17. Machado AW. 10 Commandments of smile esthetics. Dental Press J Orthod. 2014;19(4):136-57.

18. Kuhlman DC, Lima TA, Duplat CB, Capelli Junior J. Esthetic perception of orthodontic appliances by Brazilian children and adolescents. Dental Press J Orthod. 2016;21(5):58-66.

19. Moon RJ, Millar BJ. Dental aesthetics: a study comparing patients' own opinions with those of dentists. Open J Stomatol. 2017;7(17):225-33.

20. Stroede CL, Sadek H, Navalgund A, Kim DG, Johnston WM, Schricker SR, et al. Viscoelastic properties of elastomeric chains: an investigation of pigment and manufacturing effects. Am J Orthod Dentofacial Orthop. 2012;141(3):315-26.

21. Guimarães GS, Morais LS, Souza MMG, Elias CN. Superficial morphology and mechanical properties of in vivo aged orthodontic ligatures. Dental Press J Orthod. 2013;18(3):107-12.

22. Antony PJ, Paulose J. An in-vitro study to compare the force degradation of pigmented and non-pigmented elastomeric chains. Indian J Dent Res. 2014;25(2):208-13.

23. Quenzer JP, Lucato AS, Vedovello SAS, Valdrighi HC, Vedovello Filho M. Influence of elastic chain in the degradation of orthodontic forces: in vitro study. Rev Odontol UNESP. 2015;44(6):320-5.

24. Nakhaei S, Agahi RH, Aminian A, Rezaeizadeh M. Discoloration and force degradation of orthodontic elastomeric ligatures. Dental Press J Orthod. 2017;22(2):45-54.

25. Miotti LL, Nicoloso GF, Durand LB, Susin AH, Rocha RO. Color stability of a resin composite: effect of the immersion method and surface treatments. Indian J Dent Res. 2016;27(2):195-9.

26. Samra APB, Pereira SK, Delgado LC, Borges CP. Color stability evaluation of aesthetic restorative materials. Braz Oral Res. 2008;22(3):205-10.

Dental Press Journal of
ORTHODONTICS

Volume 26 - Number 2 - Online

ORIGINAL ARTICLE

https://doi.org/10.1590/2177-6709.26.2.e2119244.oar

Influence of malocclusion on oral health-related quality of life in children: a seven-year cohort study

Jocelito **TONDOLO JUNIOR**[1]
https://orcid.org/0000-0002-2499-4893

Jessica Klöckner **KNORST**[1]
https://orcid.org/0000-0001-7792-8032

Gabriele Rissotto **MENEGAZZO**[1]
https://orcid.org/0000-0002-4181-0267

Bruno **EMMANUELLI**[1,2]
https://orcid.org/0000-0002-9226-0832

Thiago Machado **ARDENGHI**[1] ✉
https://orcid.org/0000-0002-5109-740X

Submitted: July 08, 2019 • **Revised and accepted:** November 05, 2019

✉ thiardenghi@hotmail.com

How to cite: Tondolo Junior J, Knorst JK, Menegazzo GR, Emmanuelli B, Ardenghi TM. Influence of malocclusion on oral health-related quality of life in children: a seven-year cohort study. Dental Press J Orthod. 2021;26(2):e2119244.

(1) Universidade Federal de Santa Maria, Departamento de Estomatologia, Faculdade de Odontologia (Santa Maria/RS, Brazil). (2) Universidade Regional Integrada do Alto Uruguai e das Missões - URI (Erechim/RS, Brazil).

ABSTRACT

Objective: To assess the influence of early childhood malocclusion on oral health-related quality of life (OHRQoL).

Methods: 7-year cohort study involving 639 preschoolers (1 to 5 years) who had been evaluated initially with a survey conduced in 2010. Children completed the Brazilian version of the Child Perception Questionnaire (CPQ8-10) to assess OHRQoL during the follow-up period. Exploratory variables were collected at baseline, including the presence and severity of malocclusion (overjet and lip coverage). Socioeconomic characteristics, oral health behavior, and patterns of dental attendance were also investigated. A multilevel Poisson regression model was used to fit the association between malocclusion and OHRQoL. With this approach, incidence rate ratio (IRR) and 95% confidence intervals (95% CI) were calculated.

Results: A total of 449 children were re-evaluated (follow-up rate, 70.3%). The prevalence of accentuated overjet and inadequate lip coverage was 13.5% and 11.9%, respectively. The mean (±SD) CPQ8-10 score was 10.57±10.32. The presence of inadequate lip coverage was associated with higher overall mean CPQ8-10 scores (IRR 1.51; 95% CI 1.29-1.77), and social well-being, emotional well-being, and functional limitation domains. Children with accentuated overjet (>3mm) also demonstrated higher overall scores on the CPQ8-10 than their normal counterparts. The presence of this condition also influenced the oral symptom (IRR 1.29; 95% CI 1.08-1.53) and emotional well-being (IRR 1.30; 95% CI 1.02-1.66) domains.

Conclusion: Results of the present study suggest that early childhood malocclusion is a risk factor for low OHRQoL in future.

Keywords: Children. Cohort study. Malocclusion. Quality of life. Risk factor.

RESUMO

Objetivo: Avaliar a influência da má oclusão na primeira infância na qualidade de vida relacionada à saúde bucal (QVRSB). **Métodos:** Este estudo de coorte de 7 anos envolveu 639 pré-escolares (1 a 5 anos) que foram avaliados inicialmente em um levantamento transversal conduzido em 2010. As crianças completaram a versão brasileira do *Child Perception Questionnaire* (CPQ8-10) para avaliar sua QVRSB no período do acompanhamento. Variáveis exploratórias foram coletadas na linha de base, incluindo a presença e severidade de má oclusão (sobressaliência e cobertura labial). Características socioeconômicas, hábitos de saúde bucal e padrões de assistência odontológica também foram investigados. Um modelo de regressão de Poisson multinível foi utilizado para medir a associação entre má oclusão e QVRSB. Com essa abordagem, calculou-se a razão de taxa de incidência (IRR, *incidence rate ratio*) e o intervalo de confiança de 95% (IC 95%). **Resultados:** No total, 449 crianças foram reavaliadas (taxa de acompanhamento de 70,3%). A prevalência de sobressaliência acentuada e cobertura labial inadequada foi de 13,5% e 11,9%, respectivamente. A média±DP de pontuação do CPQ8-10 foi 10,57±10,32. A presença de selamento labial inadequado foi associada com maiores médias na pontuação total do CPQ8-10 (IRR 1,51; IC 95% 1,29-1,77) e nos domínios de bem-estar social, bem-estar emocional e limitação funcional. Crianças com sobressaliência acentuada (>3 mm) também demonstraram médias nas pontuações do CPQ8-10 total maiores do que suas contrapartes normais. A presença dessa condição também influenciou os domínios de sintomas bucais (IRR 1,29; IC 95% 1,08-1,53) e bem-estar emocional (IRR 1,30; IC 95% 1,02-1,66). **Conclusão:** Os resultados do presente estudo sugerem que a má oclusão na primeira infância é um fator de risco para baixa QVRSB no futuro.

Palavras-chave: Criança. Estudo de coorte. Fator de risco. Má oclusão. Qualidade de vida.

INTRODUCTION

The current definition of oral health reflects physiological, social, and psychological aspects important to the quality of life.[1] The concept of oral health-related quality of life (OHRQoL) comprises a multidimensional and subjective perception of well-being. It is not restricted to only the physical and psychological effects of treatments, but also involves several interconnected spheres of physical, familial, and environmental questions.[2,3] Notwithstanding, OHRQoL has been defined as a complement to clinical measurements to document the impact of oral disorders on an individual's activities of daily life.[4]

Malocclusion is defined as a change in growth and development that affects tooth occlusion. It is considered to be a public health problem and is highly prevalent. Data from the most recent Brazilian national oral health survey revealed that approximately 37.6% of 12-year-old children exhibited some type of malocclusion.[5] Non-aesthetic occlusal characteristics, especially in children, have been associated with unfavorable social interactions, impairing social and psychological well-being.[6]

Previous studies have assessed the association between occlusal disorders and OHRQoL of children and adolescents.[7-10] Children with malocclusion report worse OHRQoL than their normal (i.e., non-malocclusion) counterparts.[9-11] It occurs especially when malocclusion is located in the

anterior region, such as anterior open bite and accentuated overjet.[9-11] Despite this evidence, most studies have been cross-sectional in design, which prevents the assessment of causality. Therefore, longitudinal studies would be more useful in evaluating the influence of the cumulative effect of early malocclusion exerts on OHRQoL.[12]

Knowledge of changes in the dental transition stage could be important to the implementation of preventive approaches for children in this age group. Furthermore, it has been shown that malocclusion and its consequences are not only reflected in childhood, but may persist throughout life.[13] Thus, the aim of the present cohort study was to assess the influence of early childhood malocclusion on OHRQoL. Our hypothesis was that children who experienced malocclusion in early childhood will report a worse OHRQoL than their normal counterparts.

MATERIALS AND METHODS

STUDY DESIGN AND SAMPLE

An epidemiological oral health survey was performed in 2010 during the Children's National Vaccination Day, in Santa Maria, Brazil. Santa Maria is a city located in southern region of Brazil. In 2010 had an estimated population of 263,403, which included 27.520 children <6 years of age. A random sample group was selected from among all children who attended health centers in the municipality on the National Children's Vaccination Day.

A total of 639 preschool children from all administrative regions of the city were orally examined by 15 examiners who were previously trained and calibrated. A multistage sampling considered all health centers with a dental office as primary survey units, and 15 out of 28 health centers were randomly selected. Each health center is responsible for vaccinating children living in that area. Caregivers of the children completed a semi-structured questionnaire designed to collect data regarding socioeconomic status, health behaviors, and the pattern of use of dental services. Details regarding the methodology followed in this first phase have been published.[14]

At follow-up (on average, 7 years later), sample planning was based on all children who were previously evaluated (n = 639). Data collection for follow-up was performed from January 2017 to March 2018 through telephone calls to schedule evaluations, and visits to children's schools and households. After the children were located, they answered a questionnaire to assess OHRQoL. The sample size calculation accounted for an alpha error probability of 0.05, a mean score of CPQ8-10 (± standard deviation [SD]) of the exposed group (with malocclusion) of 10.9±10.7, and a mean of the unexposed group (without malocclusion) of 8.7±8.4, with a sample power of 99%.

VARIABLES

Data regarding OHRQoL, the outcome measure of this study, were obtained at follow-up (T_2). Previously trained interviewers applied the Brazilian version of the Child Perception Questionnaire (CPQ 8-10), which was translated and validated for Brazilian children 8 to 10 years of age.[15-17] The CPQ8-10 comprises 25 questions divided into four domains: oral symptoms (5 questions); functional limitations (5 questions); emotional well-being (5 questions); and social well-being (10 questions). Each question has five possible answers scored on a Likert scale scored 0 to 4. Overall scores ranged from 0 to 100, with higher scores indicating worse levels of OHRQoL.

The assessment of malocclusion, the main predictor of this study, was obtained through baseline examinations.[14] The children were examined in health centers in dental chairs with conventional lighting, using a flat dental mirror, periodontal probe (CPI, "ball point"), and damp gauze. The variables used to measure occlusal disturbances were overjet and lip coverage. Overjet was measured in millimeters and, for analysis, was dichotomized as present (>3mm) or absent (≤3mm). Lip coverage was recorded and analyzed as adequate (when the lips covered the anterior teeth completely at rest) or inadequate (when most of tooth crown was exposed and visible).[14]

Socioeconomic characteristics of the sample were recorded at baseline and included sex, annual household income, household overcrowding, mother's education, and dental service attendance. The annual household income was collected in Real (R$-Brazilian cure - R$3.80 it was equivalent to approximately USD$1.00) and then categorized into approximate quartiles. Household crowding was evaluated according to the ratio of number of individuals to the number of rooms in a house (except the bathroom) and transformed into quartiles for analysis. Maternal schooling was collected as years of study, and categorized as completed elementary school (≥ 8 years) and those with < 8 years of education. Dental service attendance was measured according to the reason the child visited the dentist in the previous 6 months and was categorized as routine (score = 0), non-routine (score = 1), and no visit (score = 2). The feasibility of the questionnaires used was previously assessed in a sample of 20 parents during the calibration process. These parents were not part of the final sample.

STATISTICAL ANALYSIS

Data were analyzed using STATA version 14.0 (StataCorp LLC, College Station, TX, USA). The primary outcome measure of this study were overall and domain-specific CPQ8-10 scores. The differences between participants and non-participants

were assessed using the chi-squared test. Descriptive statistics were used to describe the characteristics of the sample at baseline (T_1) and at follow-up (T_2).

Adjusted multilevel Poisson regression models were used to fit the association between early childhood malocclusion characteristics (overjet and lip coverage) and OHRQoL at follow-up. The multilevel structure of analysis considered individuals (level 1) nested into 15 health centers (level 2). The results are presented as incidence rate ratio (IRR) and respective 95% confidence interval (CI). Variables with p-value <0.20 in the unadjusted analysis were considered in the multivariable models.

ETHICAL CONSIDERATIONS

The study protocol was approved by the Committee of Ethics in Research of the Federal University of Santa Maria (CAAE 54257216.1.0000.5346). All children consented to participate, and their parents or legal guardians signed an informed consent form.

RESULTS

Of 639 children who were examined at baseline, 439 were re-examined at follow-up (70.3% follow-up rate). The reasons for non-participation were refusal to participate in the study (n=9) or the child could not be found (n=181). Comparing participants' and non-participants' baseline characteristics (chi-squared

test), statistical differences regarding sex ($p = 0.28$), maternal education ($p = 0.35$) and overjet ($p = 0.25$) were not found. However, non-participants had a significantly higher annual income than the re-examined children ($p < 0.05$).

Demographic, socioeconomic, and oral health characteristics of the participants evaluated at baseline (T_1) and follow-up (T_2) are presented in Table 1. The mean age of children evaluated at baseline and follow-up was 2.8±1.4 and 10.0±1.4 years, respectively. Of the re-examined children, 229 (51%) were girls. Most of the participants in both evaluations were in the lowest household income quartiles. At baseline, the prevalence of accentuated overjet and inadequate lip coverage was 13.5% and 11.9%, respectively.

Unadjusted relationships between overjet and lip coverage, with overall and domain-specific CPQ8-10 scores, are presented in Table 2. The overall CPQ8-10 scores were statistically associated with overjet ($p < 0.05$). Children who exhibited accentuated overjet and inadequate lip coverage at baseline had higher CPQ8-10 scores in the emotional well-being domain at follow-up, when compared with their normal counterparts.

Table 1: Comparison of baseline characteristics between the group of children who were followed up and the group that did not receive follow-up.

Variables	Followed-up children	Non-participants children at T_2[a]	p*
	n (%)	n (%)	
Sex			
Boys	220 (68.3)	102 (31.7)	0.28
Girls	229 (72.2)	88 (27.8)	
Maternal education			
≥ 8 years of formal education	246 (68.9)	111 (31.1)	0.35
< 8 years of formal education	199 (72.4)	76 (27.6)	
Household income in R$[b]			
Lowest (1st quartile)	94 (68.6)	43 (31.4)	
Medium lowest (2nd quartile)	129 (75.0)	43 (25.0)	0.03
Medium highest (3rd quartile)	128 (75.3)	42 (24.7)	
Highest (4th quartile)	75 (61.0)	48 (39.0)	
Household crowding in people/room			
Lowest (1st quartile)	147 (66.5)	74 (33.5)	
Medium lowest (2nd quartile)	158 (73.8)	56 (26.2)	0.16
Medium highest (3rd quartile)	34 (64.2)	19 (35.8)	
Highest (4th quartile)	107 (74.8)	36 (25.2)	
Dental attendance			
Routine	63 (67.0)	31 (33.0)	0.64
Non-routine	30 (75.0)	10 (25.0)	
No visit	349 (70.4)	147 (29.6)	
Overjet			
< 3mm	292 (72.1)	113 (27.9)	0.25
> 3mm	41 (65.1)	22 (34.9)	
Lip coverage			
Adequate	410 (71.0)	129 (29.0)	0.47
Inadequate	38 (68.0)	54 (32.0)	

*p-value of chi-square test. [a]T_2: 7-year follow-up. [b]R$: Brazilian Reais (R$3.80 it was equivalent to US$1.00 approximately).

Table 2: Demographic, socioeconomic characteristics and oral health status of the sample.

Variables	Baseline (T_1)[a] (n= 639)	Follow-up (T_2)[b] (n= 449)
	n (%)	n (%)
Sex		
Boys	322 (50.4)	220 (49.0)
Girls	317 (49.6)	229 (51.0)
Maternal education		
≥ 8 years of formal education	357 (56.5)	246 (55.3)
< 8 years of formal education	275 (43.5)	199 (44.7)
Household income in R$[c]		
Lowest (1st quartile)	137 (22.8)	94 (22.1)
Medium lowest (2nd quartile)	172 (28.6)	129 (30.3)
Medium highest (3rd quartile)	170 (28.2)	128 (30.1)
Highest (4th quartile)	123 (20.4)	75 (17.6)
Household crowding in people/room		
Lowest (1st quartile)	221 (35.0)	147 (33.0)
Medium lowest (2nd quartile)	214 (33.9)	158 (35.4)
Medium highest (3rd quartile)	53 (8.4)	34 (7.6)
Highest (4th quartile)	143 (22.7)	107 (24.0)
Dental attendance		
Routine	94 (14.9)	63 (14.2)
Non-routine	40 (6.4)	30 (6.8)
No visit	496 (78.7)	349 (79.0)
Overjet		
< 3mm	405 (86.5)	292 (87.7)
> 3mm	63 (13.5)	41 (12.3)
Lip coverage		
Adequate	547 (88.1)	410 (91.5)
Inadequate	74 (11.9)	38 (8.5)

Taking into account the sampling weight. Values lower than 639 or 449 due to missing data. [a]T_1: baseline. [b]T_2: 7-year follow-up. [c]R$: Brazilian Real (R$3.80 it was equivalent to US$1.00 approximately).

The unadjusted analysis between the malocclusion variables and OHRQoL is found in Table 3. The results of the multilevel adjusted analysis for possible confounding covariates in association with malocclusion and OHRQoL are shown in Table 4. The presence of inadequate lip coverage was associated with higher overall mean CPQ8-10 (IRR 1.51 [95% CI 1.29-1.77]), social well-being (IRR 2.05 [95% CI 1.42-2.95]), emotional well-being (IRR 1.58 [95% CI 1.13-2.20]) and functional limitation (IRR 1.94 [95% CI 1.38-2.74]) domain scores. Children with accentuated overjet (>3mm) demonstrated higher overall CPQ8-10 scores than their normal counterparts. The presence of this condition also influenced the oral symptoms (IRR 1.29 [95% CI 1.08-1.53]) and emotional well-being (IRR 1.30 [95% CI 1.02-1.66]) domains.

Table 3: Unadjusted association of Overall and Domain-Specific CPQ8-10 Scores at 7-year follow-up (T_2) by the Overjet and Lip coverage. Multilevel Poisson Regression.

	n (%)	Oral symptoms	Functional limitation	Emotional well-being	Social well-being	Overall CPQ8-10
		IRR[a] (95% CI)[b]	IRR[a] (95% CI)[b]	IRR[a] (95% CI)[b]	IRR[a] (95% CI)[b]	IRR[a] (95% CI)[b]
Overjet						
≤ 3mm	405 (86.5)	1	1	1	1	1
> 3mm	63 (13.5)	1.21 (1.04-1.40)*	1.05 (0.84-1.32)	1.36 (1.11-1.67)*	0.94 (0.74-1.20)	1.16 (1.05-1.27)*
Lip coverage						
Adequate	547 (88.1)	1	1	1	1	1
Inadequate	74 (11.9)	1.14 (0.99-1.29)	0.91 (0.74-1.13)	1.24 (1.03-1.48)*	1.00 (0.81-1.24)	1.08 (0.99-1.18)

*p<0.05 [a]IRR, incidence rate ratio. [b]CI, confidence interval.

Table 4: Adjusted association of Overall and Domain-Specific CPQ8-10 Scores at 7-year follow-up (T_2) by Overjet and Lip coverage. Multilevel Poisson Regression.

	Oral symptoms	Functional limitation	Emotional well-being	Social well-being	Overall CPQ8-10
	IRR[a] (95% CI)[b]	IRR[a] (95% CI)[b]	IRR[a] (95% CI)[b]	IRR[a] (95% CI)[b]	IRR[a] (95% CI)[b]
Overjet					
< 3mm	1	1	1	1	1
> 3mm	1.29 (1.08-1.53)*	0.88 (0.67-1.16)	1.30 (1.02-1.66)*	0.82 (0.61-1.01)	1.11 (0.99-1.25)
Lip coverage					
Adequate	1	1	1	1	1
Inadequate	1.11 (0.87-1.43)	1.94 (1.38-2.74)*	1.58 (1.13-2.20)*	2.05 (1.42-2.95)*	1.51 (1.29-1.77)*

*p<0.05. [a]IRR, incidence rate ratio. [b]CI, confidence interval. Multilevel model adjusted for sex, maternal education, household income, household crowding and dental attendance at baseline.

DISCUSSION

The present study assessed the influence of malocclusion on OHRQoL in a cohort of children. The main finding was that malocclusion assessed according to inadequate lip coverage and accentuated overjet (>3mm) had a negative impact on children's OHRQoL. This result supports the hypothesis that early childhood malocclusion is a risk factor for low OHRQoL over time. Our findings corroborate previous studies reporting that individuals with malocclusion experienced higher impact on OHRQoL than those without malocclusion.[8]

Individuals with accentuated overjet (>3mm) demonstrated higher overall mean CPQ8-10 scores. An analogous observation was found for the oral symptom, functional limitation,

and emotional well-being domains. Other studies have reported that among the occlusal relationships evaluated, an increased overjet was considered to be the condition that most interfered with OHRQoL.[8] Visible malocclusions, such as excessive overjet with incomplete lip coverage and diastema between the incisors, have been associated with bullying and low self-esteem among adolescents.[18,19] However, increased overjet was not associated with social well-being domain. This result can be explained by the fact that the OHRQoL questionnaire present a multidimensional structure, which has been reported in previous studies.[15,16,20,21] Furthermore, the OHRQoL is described as a multidimensional construct that results from an interaction between oral health conditions, social, and contextual factors.[3,15] In this sense, despite the participation of each domain, the impact of the accentuated overjet reflects in the overall scores of the questionnaire, thus impacting a worse OHRQoL in these children.

The presence of inadequate lip coverage was associated with higher overall mean CPQ8-10 scores, and social well-being, emotional well-being, and functional limitation domain scores. It has been established that non-aesthetic occlusal aspects can induce unfavorable social responses, thus impairing social interaction and psychological well-being of the individuals affected, primarily children.[6] Malocclusions have a large impact on OHRQoL in the social-emotional domain,[11] while a pleasant

aesthetic appearance plays an important role in social interactions and psychological well-being.[2] Thus, it is reasonable to assume that children with untreated malocclusions can experience psychological and social consequences, thus impacting their OHRQoL. Childhood experiences have a significant impact in later years, and a negative dental appearance in childhood may be an object of provocation by other children.[22,23]

Changes in dentition occur slowly and over the developmental stages of childhood and adolescence, and are often associated with non-nutritive sucking habits, such as finger or pacifier sucking, and prolonged use of bottle-feeding, which can cause occlusal and aesthetic changes produced by unfavorable positioning of the teeth and should be avoided.[24] To this end, the World Health Organization recommends that breastfeeding should be exclusive in the first six months, promoting improvement in the physical, mental and psychological health of children and reducing the need for non-nutritive sucking habits.[25] It is recommended that the time limit for the elimination of pacifiers be 3 years of age.[26] Therefore, early treatment may provide an important benefit for some children who experience teasing and negative stereotyping, and early orthodontic intervention to improve dentofacial aesthetics may improve a child's social interactions.[24]

In addition, study psychosocial factors in early adolescence is important. Adolescence is a period of transition and it is characterized by physiological, behaviors and social changes.[27] Through psychosocial theory, it is known that individuals with oral injuries can present physical and psychological pains and sufferings, contributing to stress, anxiety and worse OHRQoL.[28] These consequences may interfere in health behaviors in this age group as in the practice of deleterious habits and self-care in health.[28] Furthermore, it has been shown the changes at this stage and its consequences are not only reflected in childhood, but may persist throughout life.[13]

This study had limitations and strengths. One limitation was that we used a quantitative questionnaire. However, studies combining quantitative and qualitative measurements via questionnaires and interviews could provide more sensitive information as to how malocclusions in early childhood can affect a child's OHRQoL years later. Future studies encompassing more malocclusion characteristics are required. In addition, for this study, data were gathering in 15 out of 28 health centers, which may affect the extern validity of the study. However, the sampling considered all health centers with a dental office as primary survey units, which were equally distributed into different areas around the city. Furthermore, the selected centers represent the major sample point in their area and accounted for nearly 85% of the children attending

the vaccination program, reinforcing the representativeness of our sample. The main strengths of the present study were that it had a large cohort retention rate (70.3%) after 7 years, supporting the generalizability of our findings. Moreover, this longitudinal study assessed the influence of malocclusion on OHRQoL in a transition stage of children's dentition, providing evidence supporting the promotion of oral health in this age group to improve of quality of life throughout life.

CONCLUSION

Our findings support the hypothesis that anterior segment malocclusions have a significant influence on OHRQoL in children. The recognition of the changes established in the transitional stage from primary to permanent dentition, as well as the importance of preventive approaches for children in this phase of growth, when their occlusion has not yet reached maturity, makes it relevant to study this age group. An early diagnosis may facilitate the prevention of malocclusions through interceptive orthodontics, taking into account the promotion of health and OHRQoL of children.

AUTHORS' CONTRIBUTION

Jocelito Tondolo Júnior (JTJ):

Jessica Klöckner Knorst (JKK):

Gabriele Rissotto Menegazzo (GRM):

Bruno Emmanuelli (RE):

Thiago Machado Ardenghi (TMA):

Conception or design of the study:

JTJ, JKK, GRM, BE, TMA.

Data acquisition, analysis or interpretation:

JTJ, JKK, GRM, BE, TMA.

Writing the article:

JTJ, JKK, GRM.

Critical revision of the article:

JTJ, JKK, GRM, BE, TMA.

Final approval of the article:

JTJ, JKK, GRM, BE, TMA.

Fundraising:

TMA.

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

REFERENCES

1. Glick M, Williams DM, Kleinman DV, Vujicic M, Watt RG, Weyant RJ. A new definition for oral health developed by the FDI World Dental Federation opens the door to a universal definition of oral health. Int Dent J. 2016;66(6):322-24.

2. Gherunpong S, Sheiham A, Tsakos G. A sociodental approach to assessing children's oral health needs: integrating an oral health-related quality of life (OHRQoL) measure into oral health service planning. Bull World Health Organ. 2006;84(1):36-42.

3. Locker D, Allen F. What do measures of 'oral health-related quality of life' measure? Community Dent Oral Epidemiol. 2007;35(6):401-41.

4. Sischo L, Broder HL. Oral health-related quality of life: what, why, how, and future implications. J Dent Res. 2011;90(11):1264-70.

5. Brasil. Ministério da Saúde. Secretaria de Atenção à Saúde. Departamento de Atenção Básica. Projeto SB Brasil 2010: condições de saúde bucal da população brasileira 2010: resultados principais. Brasília, DF: Ministério da Saúde; 2011.

6. Scheffel DL, Jeremias F, Fragelli CM, Santos-Pinto LA, Hebling J, Oliveira Jr OB. Esthetic dental anomalies as motive for bullying in schoolchildren. Eur J Dentistry. 2014;8(1):124-8.

7. Paula JS, Leite IC, Almeida AB, Ambrosano GM, Mialhe FL. The impact of socioenvironmental characteristics on domains of oral health-related quality of life in Brazilian schoolchildren. BMC Oral Health. 2013;13:10.

8. Sardenberg F, Martins MT, Bendo CB, Pordeus IA, Paiva SM, Auad SM, et al. Malocclusion and oral health-related quality of life in Brazilian school children. Angle Orthod. 2013;83(1):83-9.

9. Scapini A, Feldens CA, Ardenghi TM, Kramer PF. Malocclusion impacts adolescents' oral health-related quality of life. Angle Orthod .2013;83(3):512-8.

10. Rosa GN, Del Fabro JP, Tomazoni F, Tuchtenhagen S, Alves LS, Ardenghi TM. Association of malocclusion, happiness, and oral health-related quality of life (OHRQoL) in schoolchildren. J Public Health Dent. 2016;76(2):85-90

11. Kragt L, Dhamo B, Wolvius EB, Ongkosuwito EM. The impact of malocclusions on oral health-related quality of life in children — a systematic review and meta-analysis. Clin Oral Investig. 2015;20(8):1881-94.

12. Horta BL, Wehrmeister FC. As coortes e as análises de ciclo vital, qual é a sua importância? Cad Saúde Pública. 2017;33(3).

13. Holst D, Schuller AA. Oral health in a life-course: birth-cohorts from 1929 to 2006 in Norway. Community Dent Health. 2012;29(2):134-43.

14. Piovesan C, Ardenghi TM, Guedes RS, Ekstrand KR, Braga MM, Mendes FM. Activity assessment has little impact on caries parameters reduction in epidemiological surveys with preschool children. Community Dent Oral Epidemiol. 2012;41(3):204-11.

15. Jokovic A, Locker D, Tompson B, Guyatt G. Questionnaire for measuring oral health-related quality of life in eight- to ten-year-old children. Pediatr Dent. 2004;26(6):512-8.

16. Barbosa TS, Tureli MC, Gavião MB. Validity and reliability of the Child Perceptions Questionnaires applied in Brazilian children. BMC Oral Health. 2009;9:13.

17. Foster Page LA, Boyd D, Thomson WM. Do we need more than one Child Perceptions Questionnaire for children and adolescents? BMC Oral Health. 2013;13:26.

18. Trulsson U, Strandmark M, Mohlin B, Berggren U. A qualitative study of teenagers' decisions to undergo orthodontic treatment with fixed appliance. J Orthod. 2002;29(3):197-204.

19. Helm S, Petersen PE, Kreiborg S, Solow, B. Effect of separate malocclusion traits on concern for dental appearance. Community Dent Oral Epidemiol. 1986;14(4):217-20.

20. John MT. Exploring dimensions of oral health-related quality of life using experts' opinions. Qual Life Res. 2007;16(4):697-704.

21. Traebert J, Lacerda JT, Thomson WM, Page LF, Locker D. Differential item functioning in a Brazilian-Portuguese version of the Child Perceptions Questionnaire (CPQ). Community Dent Oral Epidemiol. 2010;38(2):129-35.

22. Shaw WC, Meek SC, Jones DS. Nicknames, teasing, harassment and the salience of dental features among school children. Br J Orthod. 1980;7(2):75-80.

23. Damon W, Hart D. The development of self-understanding from infancy through adolescence. Child Development. 1982;53(4):841-64.

24. Dann C, Phillips C, Broder HL, Tulloch C. Self-concept, Class II malocclusion, and early treatment. Angle Orthod. 1995;65(6):411-6.

25. World Health Organization (WHO). The optimal duration of exclusive breastfeeding: report of an expert consultation. Geneva; 2001.

26. Serra-Negra JC, Dadalto ECV. Hábitos bucais deletérios. In: Manual de referências para procedimentos clínicos em odontopediatra. Vitória: Associação Brasileira de Odontopediatria; 2009. p. 394-9.

27. World Health Organization (WHO). Nutrition in adolescence: issues and challenges for the health sector: issues in adolescent health and development. Geneva; 2005.

28. França, S. Capital social, religiosidade e fatores psicossociais no contexto da saúde. Rev Assoc Paul Cir Dent. 2017;71(1):6-12.

Dental Press Journal of
ORTHODONTICS

Volume 26 - Number 2 - Online

BBO'S SELECTED ARTICLE

https://doi.org/10.1590/2177-6709.26.2.e21bbo2

Mandibular orthopedic advancement in different facial patterns and distinct stages of skeletal maturation

Fernando Penteado Lopes da **SILVA**[1,2] ✉

https://orcid.org/0000-0003-2276-8347

Submitted: March 08, 2021 • **Revised and accepted:** March 22, 2021

✉ penteadolopesortodontia@gmail.com

How to cite: Silva FPL. Mandibular orthopedic advancement in different facial patterns and distinct stages of skeletal maturation. Dental Press J Orthod. 2021;26(2):e21bbo2.

Patients displayed in this article previously approved the use of their facial and intraoral photographs.
The author reports no commercial, proprietary or financial interest in the products or companies described in this article.

(1) Diplomate of the Brazilian Board of Orthodontics and Facial Orthopedics. (2) Private practice (Campinas/SP, Brazil).

ABSTRACT

The Herbst appliance can be very effective in treatment of Class II patients with mandibular retrognathism. Because of the continuous action in a full-time basis, treatment time using it normally takes from six to ten months, and is usually followed by a second phase of full fixed appliances, in order to obtain both occlusal refinement and long term stability. Despite Herbst appliance's effectiveness in the occlusal and dentoalveolar perspectives, its facial results may differ among patients with different growth patterns, as well as in distinct stages of skeletal maturation. In the current paper, two patients with different facial patterns are presented, who were treated under the same protocol, using Herbst and full fixed appliances in different skeletal maturation stages, and both dentoalveolar and facial results are compared and discussed.

Keywords: Herbst appliance. Class II orthopedic treatment. Mandibular retrognathism. Skeletal maturation.

RESUMO

Um número significativo de pacientes que procuram o tratamento ortodôntico apresenta má oclusão de Classe II acompanhada pelo retrognatismo mandibular. Abordagens ortopédicas para avanço mandibular são comumente utilizadas enquanto houver crescimento facial remanescente e, nesses casos, o estágio de maturação esquelética deve ser avaliado para definir a melhor época de intervenção terapêutica. Após concluída a fase ortopédica, normalmente é realizada uma segunda fase ortodôntica para refinamento oclusal, com o intuito de oferecer maior estabilidade das correções em longo prazo. No presente artigo, serão discutidos os resultados do avanço mandibular ortopédico considerando-se diferentes estágios de crescimento.

Palavras-chave: Má oclusão de Classe II. Retrognatismo mandibular. Ortopedia dentofacial. Aparelho de Herbst. Crescimento craniofacial.

INTRODUCTION

The negative effect caused by mandibular retrognathism on the face is often the reason why adult patients seek orthodontic-surgical treatment approaches.[1-5] Patients treated during craniofacial growth stages, on the other hand, may have benefits from the orthopedic mandibular advancement. The use of fixed as well as removable orthopedic appliances moves the mandible forward, in order to correct the initial sagittal discrepancy.[6]

The Herbst appliance is probably the most used fixed orthopedic device, which uses intermaxillary anchorage, by means of a telescopic mechanism, to promote orthopedic mandibular advancement. Brought back to the orthodontic literature by Pancherz, it combines both orthodontic and orthopedic effects during the correction of mandibular retrognathism, and one of its main advantages is inducing continuous mandibular advancement during rest and masticatory function.[6-10] The Herbst appliance has been studied for several years, and both dental and skeletal effects have been widely advocated.[11-13] Among these effects, the dental compensations must be highlighted, since they are present after treatment with both fixed and removable orthopedic devices.[14,15] Located mainly in mandibular anterior[16-20] and maxillary posterior[21] dentoalveolar regions, dental compensations play a fundamental role during orthopedic mandibular advancement in Class II patients' treatment.

After the orthopedic correction, a second orthodontic treatment phase is necessary, in order to obtain adjustments such as improvement of dental crowding, closing residual spaces and occlusal refinement.[22] It is widely known that a stable occlusal intercuspation obtained after mandibular advancement plays an essential role in the long term stability.[23]

However, the ideal period of orthopedic mandibular advancement treatment, using either fixed or removable devices, still remains a controversial issue among authors. Depending on the growth stage, the treatment is considered as early approach if started during deciduous or early mixed dentition, or before pubertal growth spurt; on the other hand, it is considered as a late approach if started during late mixed or permanent dentition, or during or after pubertal growth spurt. Considering this context, in which of these periods would be appropriate to start orthopedic mandibular advancement? In case of treatment during effective pubertal growth period, what would be its repercussions in the long term, and there would be stability warranties? Searching for answers to these questions, a meta-analysis was performed to evaluate if the treatment onset time would bring any difference in effects of mandibular orthopedic advancement in patients during distinct growth stages.[24] In patients treated before pubertal growth spurt, the mandibular length increased from 0.89 to 1.68mm (mean value = 1.29mm), while those patients treated

during pubertal growth spurt presented mandibular length increasing from 3.65 to 5.00mm (mean value = 4.32mm). The authors pointed out that mandibular growth can be effectively augmented only if orthopedic advancement is performed during pubertal growth periods, and also that the ideal period should be defined using appropriate methods, such as hand-wrist radiographs.

The ideal treatment period, however, is not determined solely by biological parameters. The psychosocial aspect of the patient must be considered, as well as the risk of trauma to the maxillary incisors, which is also very common in Class II patients with mandibular retrognathism. In a recent systematic review with 27 randomized clinical trials and a total of 1,251 patients, groups underwent early or late orthopedic treatment, and also no treatment samples were compared. In the comparison between early and late treatments, the only significant difference was a decreased incidence of maxillary incisor trauma, which was also found in the comparison between late treatment and no treatment groups.[25]

In the present paper, two case reports will be presented, of Class II patients treated in distinct stages of skeletal maturation, using the same protocol of mandibular orthopedic advancement, followed by a full fixed appliances orthodontic treatment.

CASE 1

DIAGNOSIS

The case 1 refers to a young male patient, at 7 years and 10 months of age, with the following chief complaints: *"excessive spaces between upper frontal teeth"* and *"chin in a backward position",* as well as some respiratory difficulty and introspective social behavior. According to the facial analysis, the mandibular retrognathism was evident, as well as the labial incompetence and a hiperdivergent growth pattern, associated with the increased lower facial height and a clockwise mandibular rotation. Despite the good position of the upper lip, the nasolabial angle was augmented. The lower lip was in a backward position and slightly everted (Fig 1). The patient had an Angle Class II division 1 malocclusion during the intermediate period of mixed dentition, associated with increased overbite and overjet (Figs 1 and 2). The hand-wrist radiograph highlighted the growth stage of the patient, which was before pubertal spurt (Fig 2). Cephalometric analysis was in accordance with facial remarks, which indicated a hyperdivergent

Figure 1: Initial extraoral and intraoral photographs.

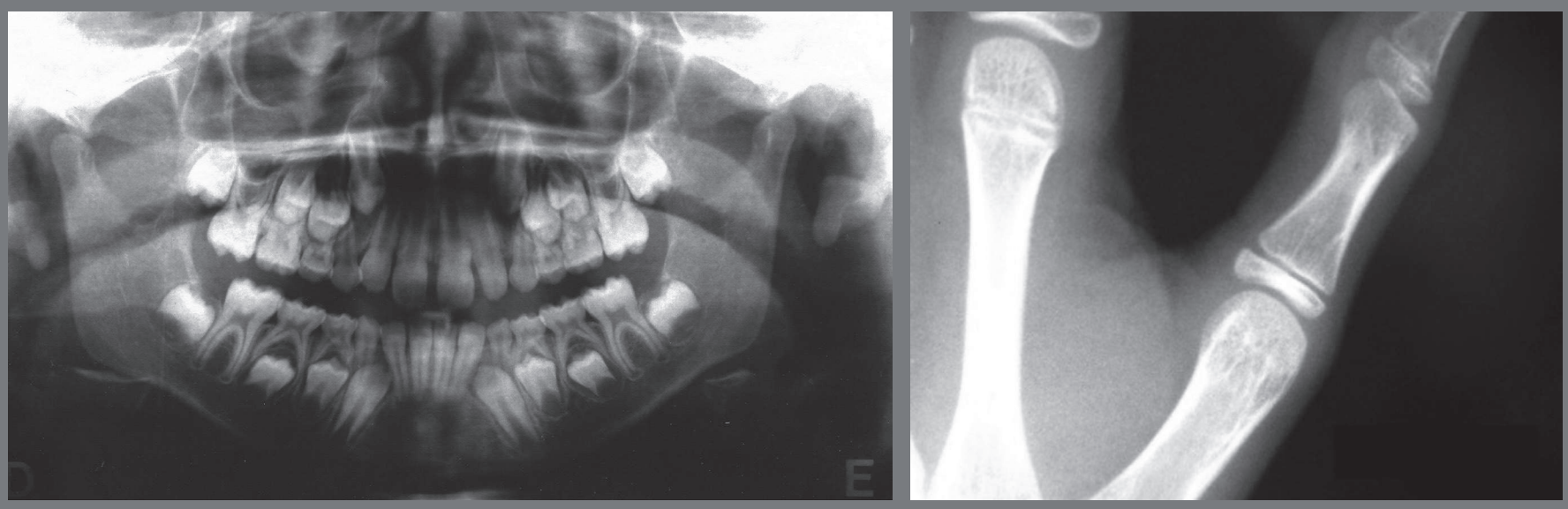


Figure 2: Initial panoramic and hand-wrist radiographs.

facial growth pattern (FMA = 27.1º, SN.GoGn = 33.5º and Y-axis = 69.5º). It was also detected a slight maxillary protrusion (SNA = 83.2º) and mandibular retrusion (SNB=76.9º), which led to an increased skeletal profile convexity (ANB = 6.3º and Convexity Angle = 12.9º) (Tab. 1). The maxillary incisors were protruded and positioned in a buccal position (1.NA = 25.9º and 1-NA = 5.5mm), while the mandibular incisors were relatively well positioned in mandibular apical base (IMPA=89.9º, 1.NB = 23.9º and 1-NB = 6.0mm) (Fig 3, Tab. 1).

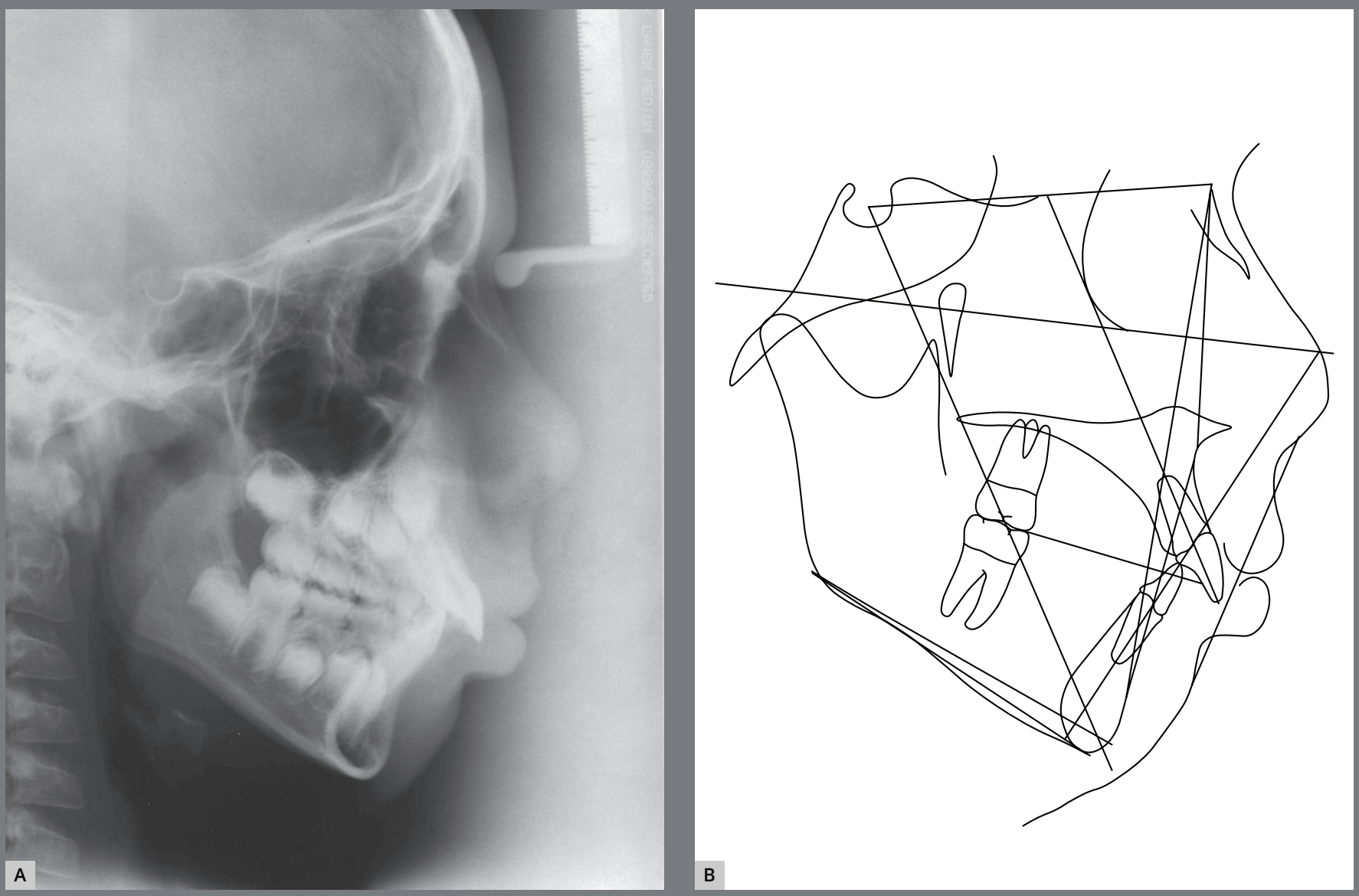


Figure 3: Initial cephalometric radiograph of facial profile **(A)** and cephalometric tracing **(B)**.

TREATMENT PLAN AND PROGRESS

Considering the functional and psychosocial issues of patient, the orthopedic mandibular advancement approach was promptly accepted by his parents. It was also explained that an orthodontic-surgical approach could be necessary in the future, in case of a unsuccessful orthopedic treatment. In these terms, the mandibular orthopedic advancement was initiated with a Herbst appliance designed for mixed dentition.[27] After the accomplishment of orthopedic approach (Phase 1), an orthodontic stage with full fixed appliances took place (Phase 2), in order to obtain occlusal refinement.

The Class II malocclusion with mandibular retrognathism is usually accompanied by a narrow maxilla,[3,6,27] and these features were also present in this case. Thus, a Rapid Maxillary Expansion (RME) was previously performed with a Haas expander, in order to adequate the maxilla before the mandibular advancement. The Herbst appliance was kept in place continually during a one-year period, and then removed when both adequate overjet and overbite were achieved. New orthodontic records were taken in permanent dentition stage, as soon as second molars erupted (Figs 4 and 5).

During the full fixed orthodontic appliances stage (Phase 2), which took place during a period of 18 months, the remaining spaces were closed and correction of the overbite was improved, as well as the maintenance of dental compensations obtained during Phase 1.

Figure 4: Intermediate extraoral and intraoral photographs after Phase 1.

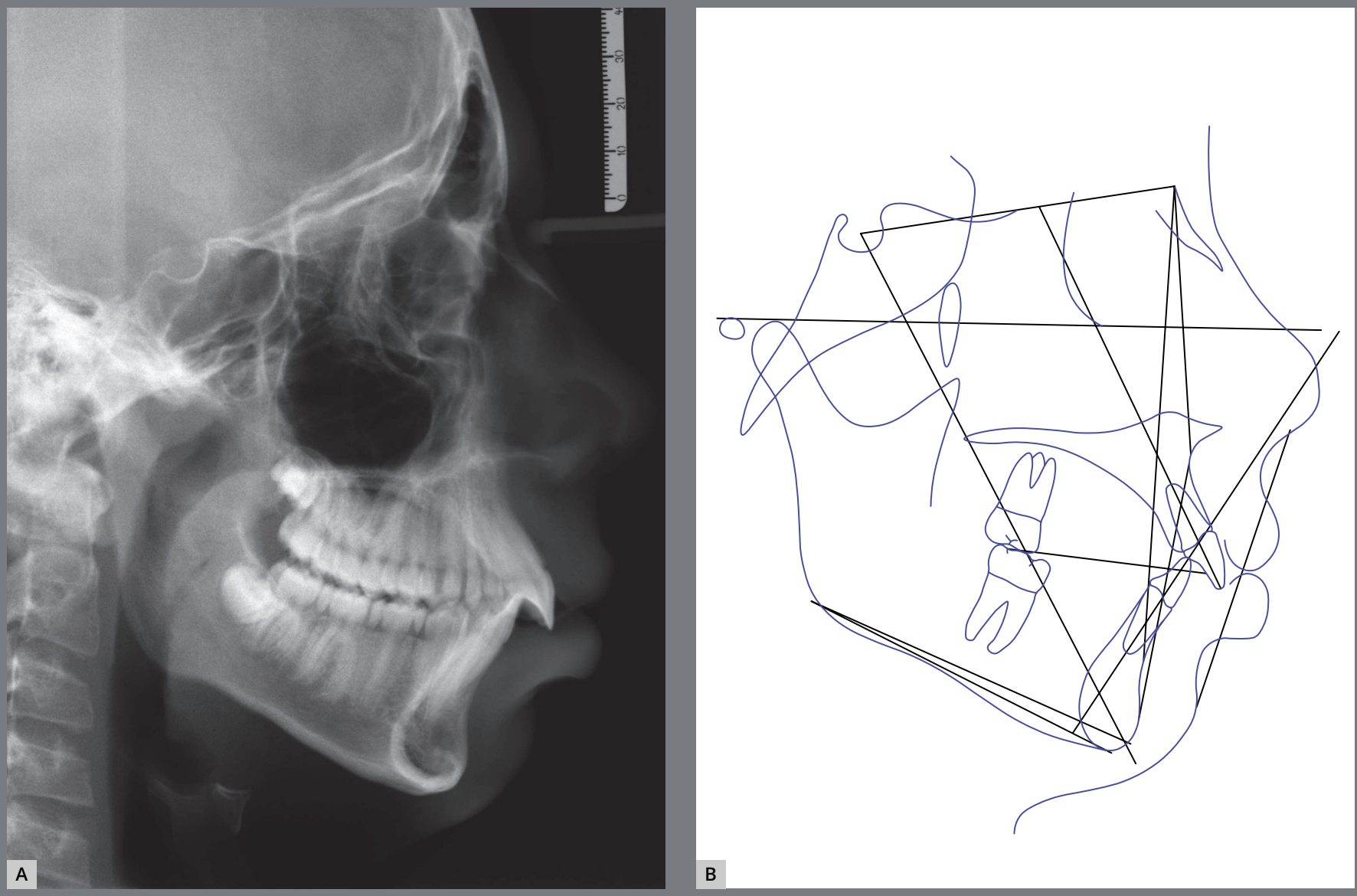


Figure 5: Intermediate cephalometric radiograph of facial profile **(A)** and cephalometric tracing **(B)** after Phase 1.

The following retention period was performed with an upper Hawley retainer and a lower fixed canine-to-canine lingual bar. In the final records, it is possible to observe the Class I dental relation, as well as the correct overjet and overbite (Figs 6, 7 and 8).

The pre- and post-treatment cephalometric tracings superimposition highlighted a clockwise mandibular rotation, with fulcrum at the condylar region. The maxillomandibular structures were actually moved to the same direction, as a consequence of the hyperdivergent facial growth pattern (Fig 9).

Figure 6: Final extraoral and intraoral photographs.

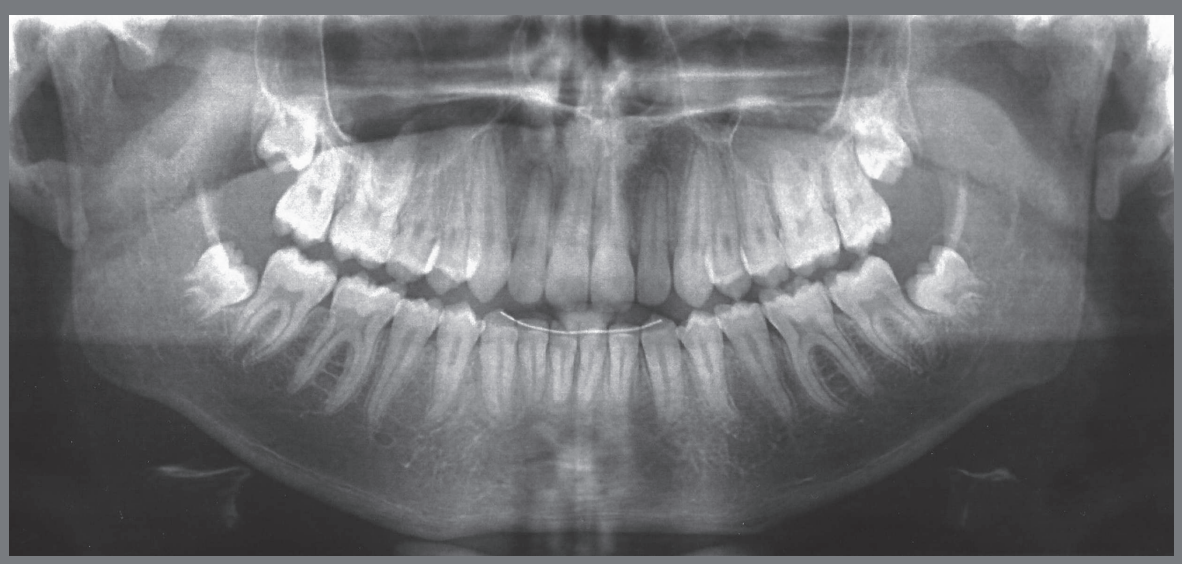


Figure 7: Final panoramic radiograph.

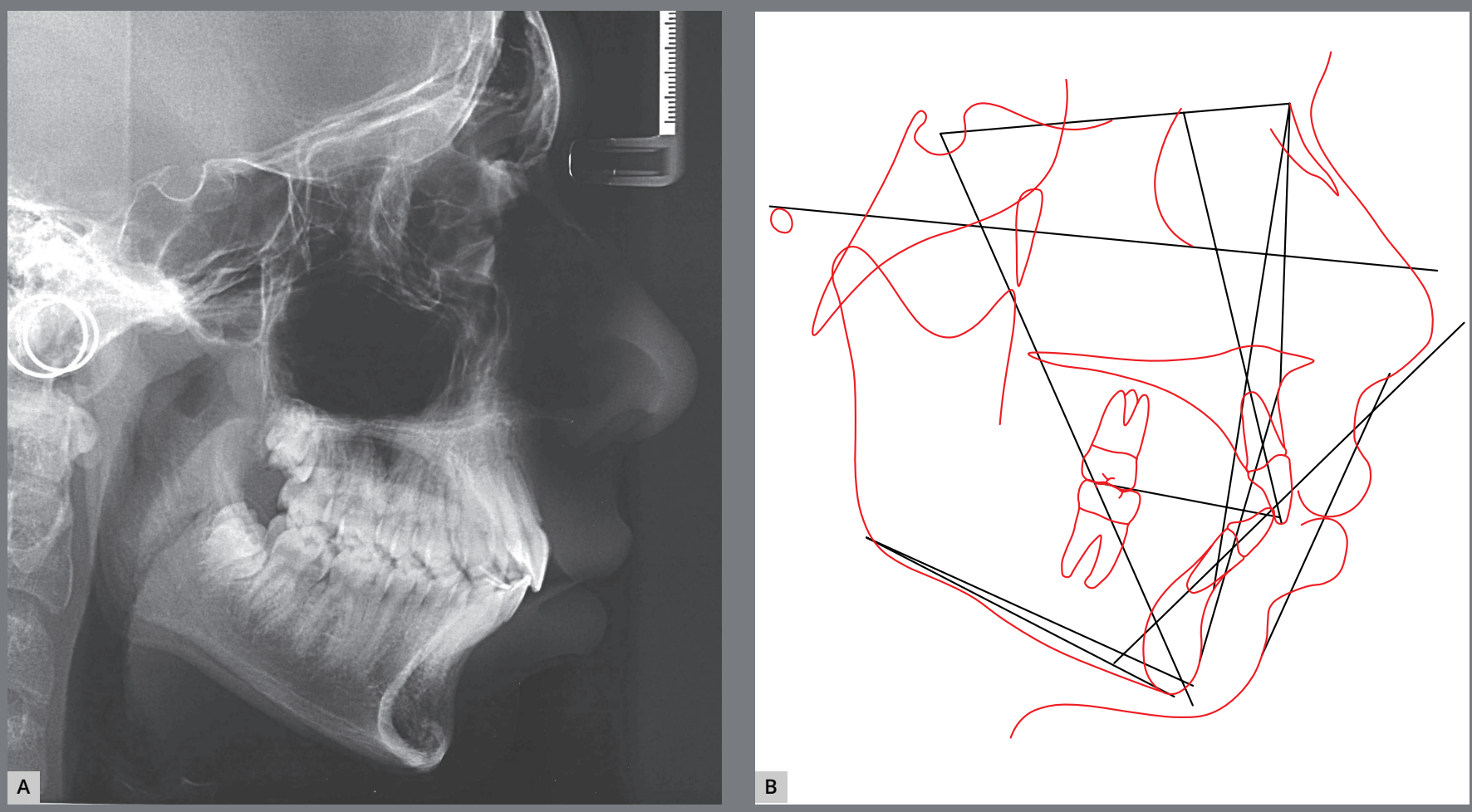


Figure 8: Final cephalometric radiograph of facial profile **(A)** and cephalometric tracing **(B)**.

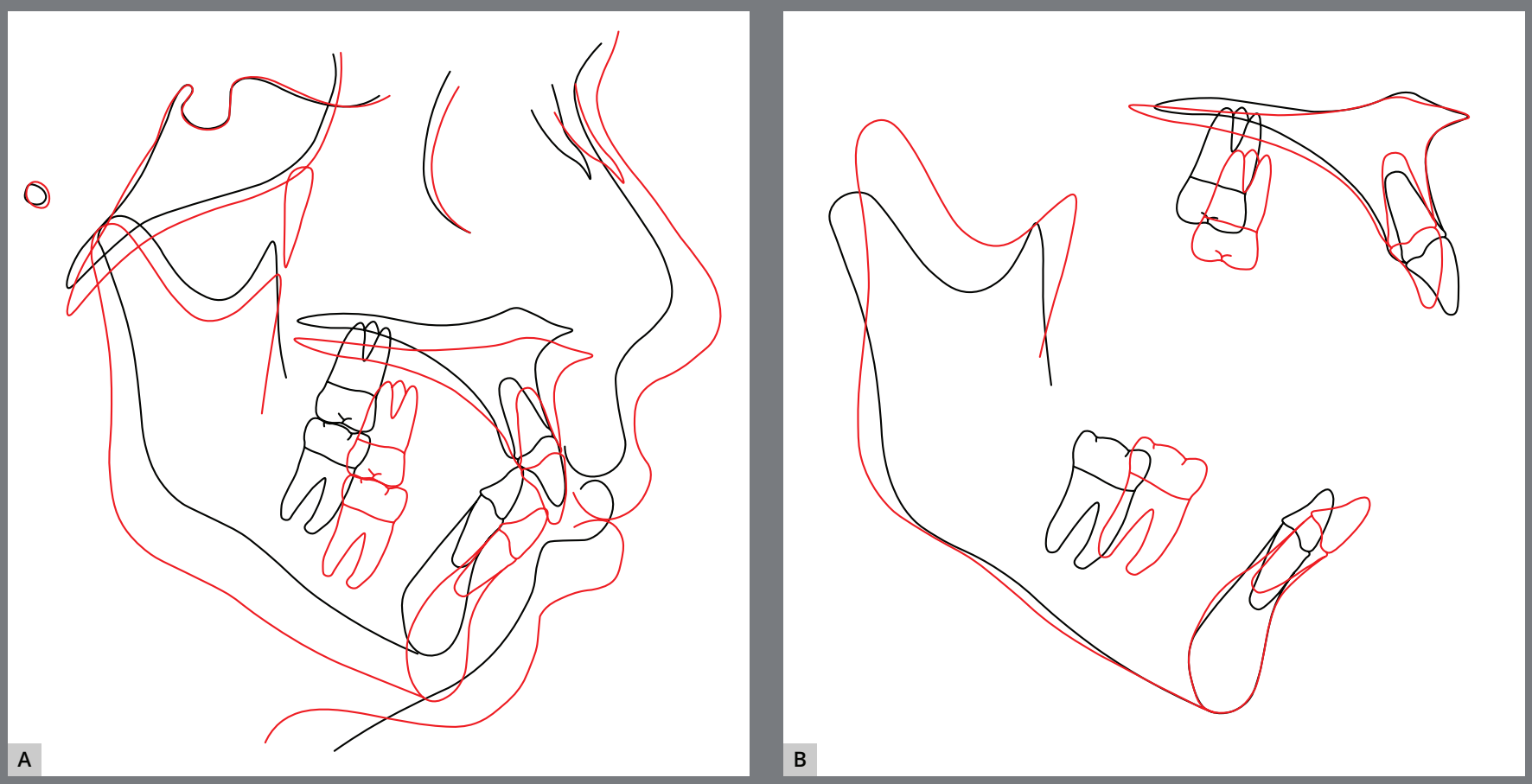


Figure 9: Total **(A)** and partial **(B)** superimpositions of cephalometric tracings at start (black line) and end (red line) of treatment.

Table 1: Cephalometric values at start **(A)** and at the end **(C)** of treatment.

	MEASURES		Normal	A	B	C	≠ A/C
Skeletal pattern	SNA	(Steiner)	82°	83.2°	84.5°	82.8°	0.4
	SNB	(Steiner)	80°	76.9°	77.4°	75.9°	1.0
	ANB	(Steiner)	2°	6.3°	7.1°	6.9°	0.6
	Wits	(Jacobson)	♀ 0 ±2mm ♂ 1 ±2mm	0.3mm	4.4mm	5.8mm	5.5
	Angle of convexity	(Downs)	0°	12.9°	14.4°	14.0°	1.1
	Y-Axis	(Downs)	59°	69.5°	71.1°	70.7°	1.2
	Facial Angle	(Downs)	87°	86.7°	87.3°	86.2°	0.5
	SN.GoGn	(Steiner)	32°	33.5°	32.9°	29.4°	4.1
	FMA	(Tweed)	25°	27.1°	25.7°	22.1°	5.0
Dental pattern	IMPA	(Tweed)	90°	89.9°	96.7°	108.6°	18.7
	$\underline{1}$.NA (degrees)	(Steiner)	22°	25.9°	20.5°	15.6°	10.3
	$\underline{1}$-NA (mm)	(Steiner)	4 mm	5.5mm	5.8mm	3.0mm	2.5
	$\overline{1}$.NB (degrees)	(Steiner)	25°	23.9°	29.8°	37.0°	13.1
	$\overline{1}$-NB (mm)	(Steiner)	4mm	6.0mm	7.7mm	8.2mm	2.2
	$\frac{1}{1}$ - Interincisal angle	(Downs)	130°	123.9°	122.6°	120.4°	3.5
	1 - APg	(Ricketts)	1mm	12.5mm	12.3mm	8.5mm	4.0
Profile	Upper Lip – Line S	(Steiner)	0mm	5.3mm	4.6mm	4.6mm	0.7
	Lower Lip – Line S	(Steiner)	0mm	7.8mm	7.7mm	7.2mm	0.6

CASE 2

DIAGNOSIS

Female patient, with 11 years and 10 months of age, sought orthodontic treatment with chief complaints related to maxillary anterior teeth crowding, as well as unaesthetic facial characteristics. The facial analysis highlighted a maxillomandibular retrusion associated to both mandibular retrognathism and increased nasolabial angle.[3] The patient presented a Class II, division 2 malocclusion at the final stage of mixed dentition, with maxillary and mandibular incisor crowding, and good labial competence (Fig 10). The hand-wrist radiograph evaluation highlighted

Figure 10: Initial extraoral and intraoral photographs.

the presence of sesamoid bone of the thumb with adequate radiopacity, as well as epiphyseal covering stage, and pointed to the peak of pubertal growth spurt (Fig 11). The cephalometric analysis indicated a good facial balance and normal growth pattern (FMA = 21.8º, SN.GoGn = 31.5º, Y-axis = 66.9º). The Class II malocclusion was correlated to the mandibular retrognathism (ANB = 6.5º, SNB = 76.5º, SNA = 83º) and to the skeletal facial

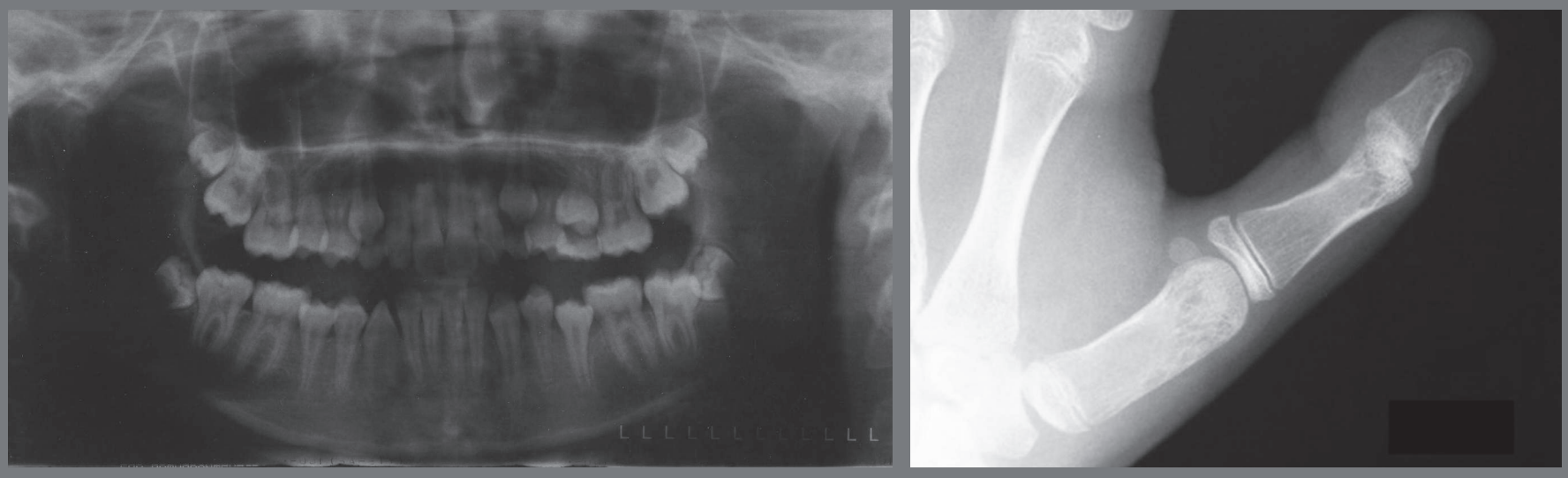


Figure 11: Initial panoramic and hand-wrist radiographs.

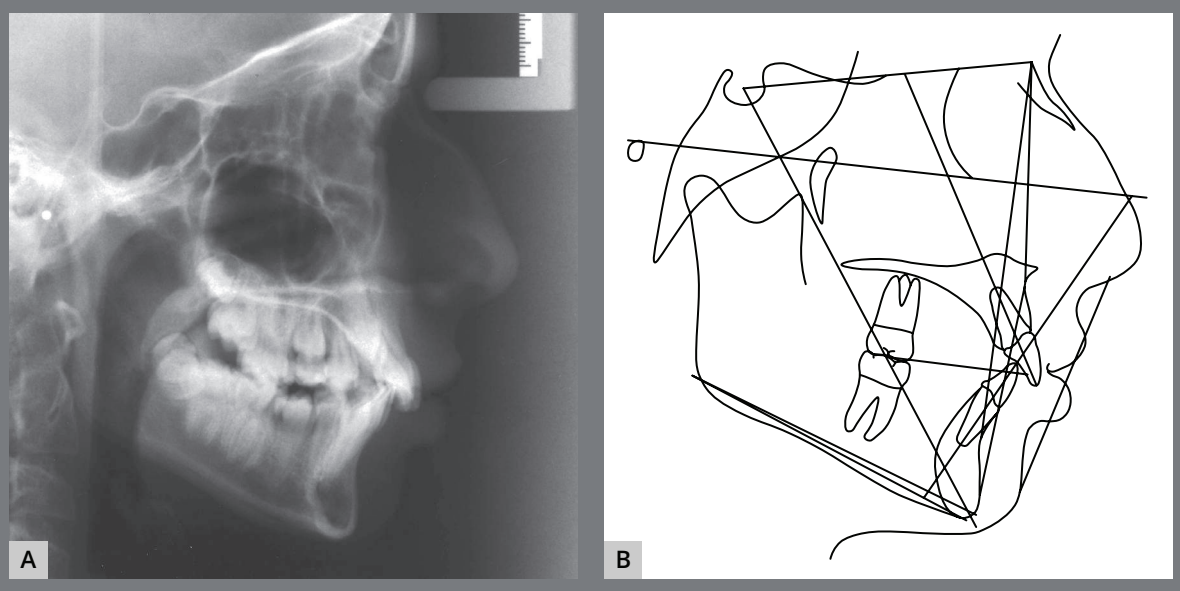


Figure 12: Initial cephalometric radiograph of facial profile **(A)** and cephalometric tracing **(B)**.

profile convexity (angle of convexity = 10.0º) (Fig 12, Tab. 2). The maxillary incisors were well positioned (1.NA = 24.9º, 1-NA = 4.1mm), while the mandibular incisors were slightly proclined (IMPA = 96.7º, 1.NB = 26.9º, 1-NB = 5.6mm) (Fig 12, Tab. 2).

TREATMENT PLAN AND PROGRESS

The mandatory decompensations on maxillary dental arch were performed before the mandibular orthopedic advancement. Thus, Rapid Maxillary Expansion (RME) followed by upper 4x2 alignment and leveling were performed. Then, orthopedic

mandibular advancement was performed with Herbst appliance, which was kept in place for a period of 10 months. After the orthopedic phase was accomplished, a full orthodontic appliances stage took place, in order to obtain occlusal refinement, for a period of 18 months. During the retention phase, the patient worn an upper Hawley and a lingual lower canine-to-canine fixed bar (Figs 13, 14 and 15).

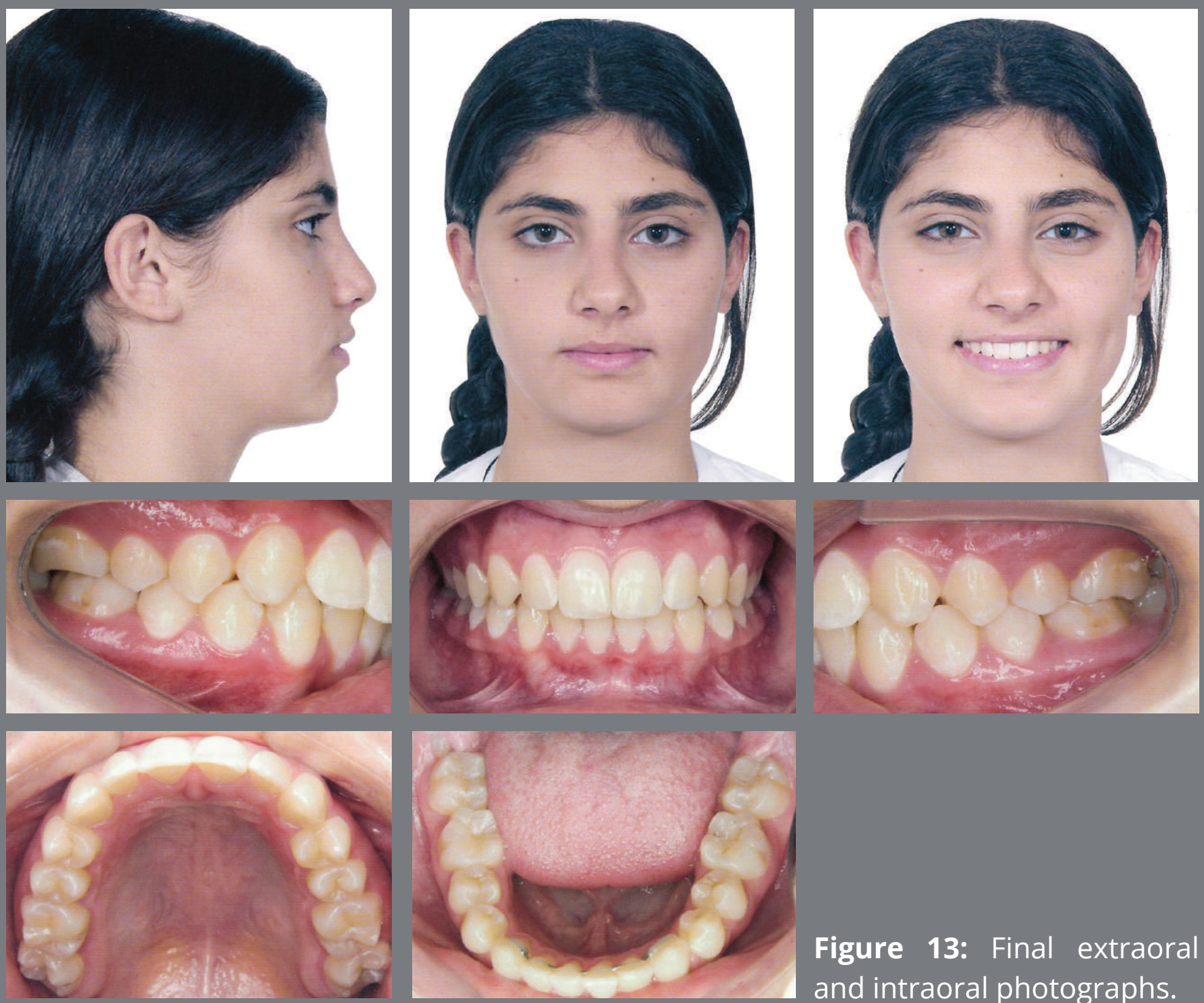


Figure 13: Final extraoral and intraoral photographs.

Figure 14: Final panoramic radiograph.

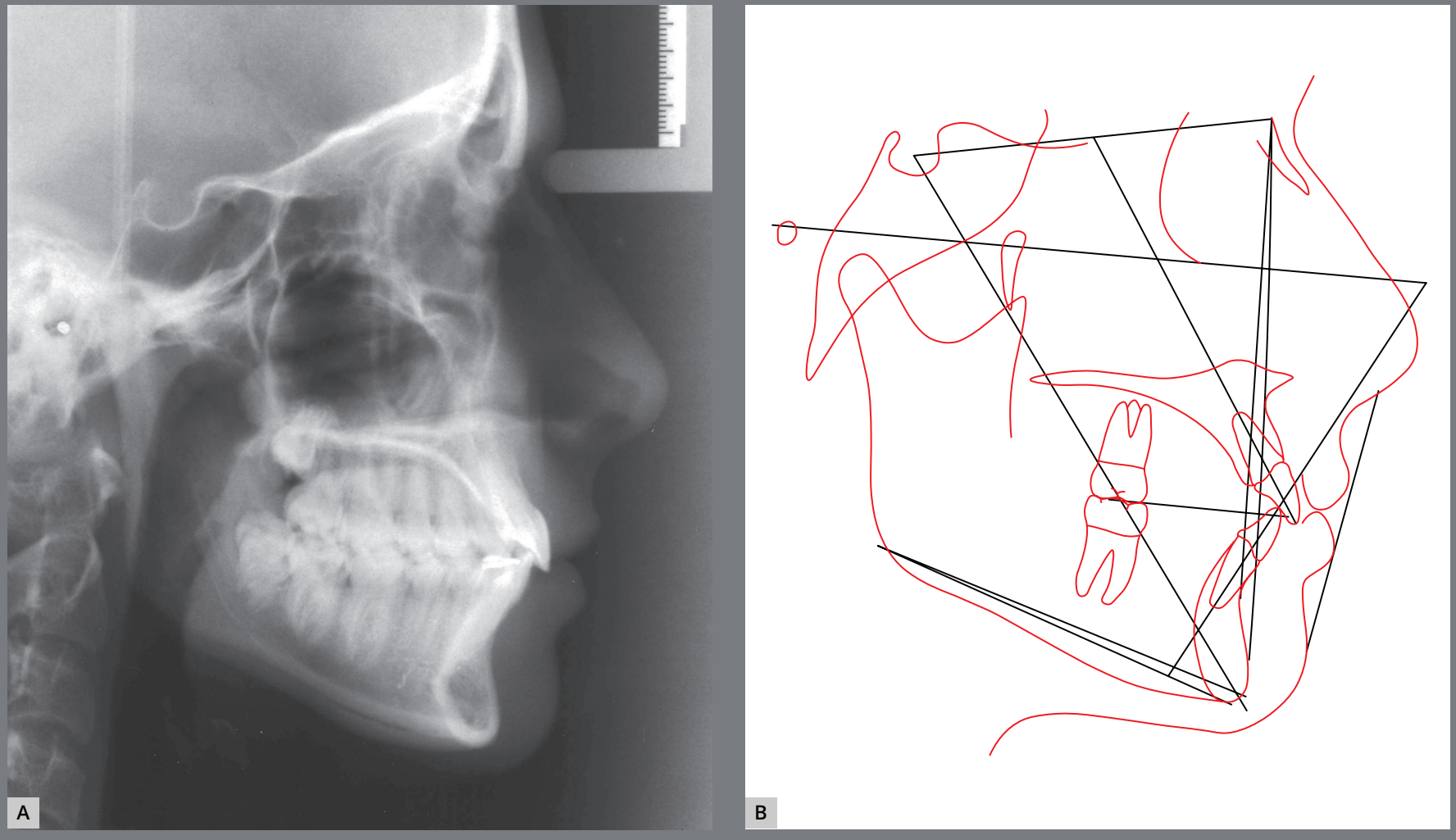


Figure 15: Final cephalometric radiograph of facial profile **(A)** and cephalometric tracing **(B)**.

Table 2: Cephalometric values at start **(A)** and at the end **(B)** of treatment.

	MEASURES		Normal	A	B	≠ A/B
Skeletal pattern	SNA	(Steiner)	82°	83°	82.6°	0.4
	SNB	(Steiner)	80°	76.5°	80.2°	3.7
	ANB	(Steiner)	2°	6.5°	2.4°	4.1
	Wits	(Jacobson)	♀ 0 ±2mm ♂ 1 ±2mm	6.0mm	1.3mm	4.7
	Angle of convexity	(Downs)	0°	10.0°	2.4°	7.6
	Y-Axis	(Downs)	59°	66.9°	64.8°	2.1
	Facial Angle	(Downs)	87°	89.3°	92.6°	3.3
	SN.GoGn	(Steiner)	32°	31.5°	28.3°	3.2
	FMA	(Tweed)	25°	21.8°	19.0°	2.8
Dental pattern	IMPA	(Tweed)	90°	96.7°	99°	2.3
	$\underline{1}$.NA (degrees)	(Steiner)	22°	24.9°	28.9°	4.0
	$\underline{1}$-NA (mm)	(Steiner)	4 mm	4.1mm	6.8mm	2.7
	$\overline{1}$.NB (degrees)	(Steiner)	25°	26.9°	29.2°	2.3
	$\overline{1}$-NB (mm)	(Steiner)	4mm	5.6mm	6.2mm	0.6
	$\frac{1}{1}$ - Interincisal angle	(Downs)	130°	122.4°	119.4°	3.0
	1 - APg	(Ricketts)	1mm	7.7mm	7.5mm	0.2
Profile	Upper Lip – Line S	(Steiner)	0mm	0.4mm	-0.9mm	1.3
	Lower Lip – Line S	(Steiner)	0mm	3.0mm	0.0mm	3.0

Along the decrease of mentolabial angle, there was also an improvement of the relationship between the upper and lower lips. Regarding the maxillary incisors, there was a slight proclination as a consequence of their long-axis correction. The maxillary cephalometric tracings superimposition evidenced a slight backward movement of point A, which probably happened as a consequence of remodeling on this region that was also depicted by decrease of SNA in the post-treatment. The maxillary molars presented slight extrusion and remained at the same anteroposterior positions. There was also extrusion movement of mandibular molars, as a consequence of the vertical dentoalveolar remodeling caused by mandibular advancement with Herbst appliance[6,7,9] (Fig 16).

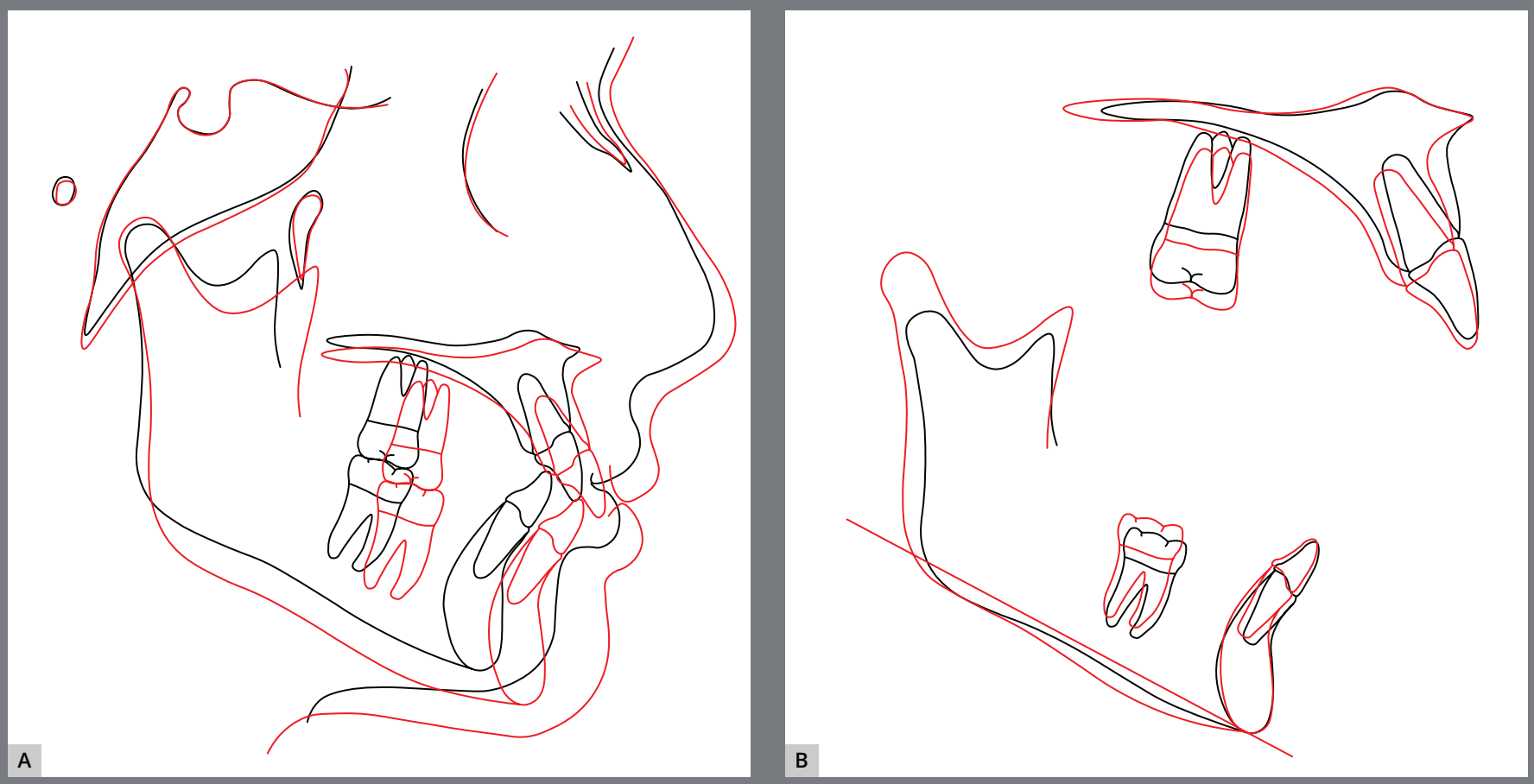


Figure 16: Total **(A)** and partial **(B)** superimpositions of cephalometric tracings at start (black line) and end (red line) of treatment.

DISCUSSION

In both cases, there was improvement of facial characteristics at the end of treatment, mainly due to the achievement of spontaneous lip contact at rest in Case 1, as well as decrease of mentolabial sulcus in Case 2. The decrease of facial profile convexity also took place in both cases at the end of treatment, and it was more remarkable in Case 2. The hyperdivergent facial pattern of Case 1 led to a more vertical than sagittal movement of the mandible. The evaluation of Table 1 highlights that cephalometric measures regarding to skeletal facial pattern increased, as a consequence of active facial growth during the period of orthopedic mandibular advancement.

The comparison of Herbst effects in different facial patterns has been studied for several years, and often presents similar results regarding to the maintenance of mandibular growth direction, as well as to a satisfactory dentoalveolar correction, as recently demonstrated by Atresh et al.[28] Regarding the characteristics of the initial malocclusions of both cases in this current paper, Class II division 1 (Case 1) and Class II division 2 (Case 2), distinct skeletal results after Herbst therapy were observed, mainly related to a more effective forward mandibular movement in the hypodivergent patient (Case 2), which was at the peak of pubertal growth spurt.

Despite some advantages, compared to other devices, specially regarding the immediate facial positive change, as well as to the full-time mandibular forward position during its use, it is reasonable to admit some limitations of Herbst appliance. The tooth-tissue-borne anchorage promotes significant dental compensation effects, as can be observed in Case 1. Furthermore, its action on the mandibular growth is only temporary.[26] In both of the presented cases, the orthopedic mandibular advancement was maintained during a one-year period in a full-time basis, as suggested by Pancherz.[29,30]

The SNB angle presented a slight increase of 0.5º in Case 1 after Herbst removal, and decreased to 1.5º at the end of full fixed appliances phase (Table 1). The angle of facial convexity increased after the mandibular advancement, and remained the same after the full fixed appliances phase. The same tendency was observed regarding the ANB angle. Considering vertical dimension, the FMA and SN.GoGn angles decreased, suggesting a slight improvement on facial growth direction. Regarding the Y-axis, however, significant changes were not observed. The possibility of inducing real additional mandibular growth is still far from being unanimity in the literature, and the amount of orthopedic effect depends mainly on facial growth pattern, as well as on the skeletal age at treatment onset.[6,30]

Bearing in mind the negative psychosocial factors present in Case 1, which were caused mainly by the mandibular retrognathism and facial characteristics, it was decided to start treatment during early mixed dentition period. This choice was made in order to improve the facial appearance of the patient as well as his self-esteem. Besides, it reduces the occurrence of trauma to the maxillary incisors.[25,31] The disadvantage of the early approach, however, relies on the long total treatment time and, usually, a less effective mandibular response to the orthopedic advancement. The active period of Herbst appliance in Case 1 lasted 10 months, which is in accordance to the recommended in the literature.[23,26,27]

In contrast to the minor skeletal changes, the dentoalveolar cephalometric alterations were evident. The maxillary incisors were significantly retracted, as depicted by the decreased 1.NA and 1-NA values at the end of treatment. Despite the slight mandibular forward movement, the mandibular incisors were significantly protruded, as a consequence of compensatory component of Class II malocclusion treatment, which took place both during the orthopedic and orthodontic phases (1.NB, 1-NB and IMPA) (Table 1). The dentoalveolar results were quite suitable, mainly related to overbite and overjet reduction, as well as to achievement of Class I molar relationship without dental extractions. These results are in agreement with literature regarding the Herbst appliance effects, such as maintenance or reduction of maxillary incisors proclination, associated to maxillary dental arch retraction, as well as mandibular incisors proclination and forward movement of the mandibular teeth,[10-15] which are linked to positive although temporary stimulus of Herbst appliance on mandibular growth, and also on condyle and glenoid fossa forward remodeling.[26,32,33]

There were no false expectations among orthodontist and parents about an ideal facial improvement, and that was very important in Case 1 treatment. In these terms, is very important to highlight the positive but transitory effect of Herbst appliance on facial profile. As expected,[26] it was achieved a

certain restriction of the forward movement of maxilla during the orthopedic phase, however with minor effect on the mandibular body length. The treatment overall result might be considered positive, mainly due to the decrease of facial convexity, associated to the achievement of spontaneous lip contact in rest position (Fig 6).

The overall result can be considered satisfactory in Case 2, as well, since both aesthetic and functional goals were achieved, mainly due to patient's good growth potential during the appropriate stage of skeletal maturation. Therefore, the orthopedic approach reduced the need for extensive tooth movement during the full orthodontic fixed appliances phase. The palatal and mandibular planes were kept on similar inclinations in both pre- and post-treatment phases, witch corroborates the good facial growth pattern of the patient.

The dentoalveolar compensatory factor, which is inherent to mandibular orthopedic advancement,[8,11,12] did not negatively impact the effectiveness of orthopedic treatment. There was great improvement on the reduction of facial profile convexity, as well as on the correction of maxillary and mandibular incisors inclination at the end of treatment.

Evaluating the final results of both cases, it is reasonable to confirm the evidences pointed out by the literature about Herbst appliance. This device is more effective on the

orthopedic treatment of hypodivergent patients, which present a more forward direction of mandibular growth,[8,11,12,32] as can be highlighted in Case 2. On the other hand, the hyperdivergent patients usually present a limited facial improvement after the same orthopedic approach, with more effect on dentoalveolar structures.[10-15,33] It must also be emphasized that the minor mandibular growth response in Case 1 can be attributed to the early skeletal maturation stage of the patient in which orthopedic treatment took place — in other words, before the peak of pubertal growth spurt.

CONCLUSION

Considering the results presented in the current paper, it can be concluded that Herbst appliance was efficient in both cases, specially in relation to dentoalveolar effects, which are necessary for Class II correction. The facial and skeletal results, however, were not similar comparing the two cases. In face of high expectations about significant orthopedic results on mandibular growth and its forward movement achieved with Herbst appliance, therefore, two key factors must be considered: the facial growth pattern and the skeletal maturation stage of the patient at treatment onset.

REFERENCES

1. Carter NE. Dentofacial changes in untreated Class II division 1 subjects. Br J Orthod. 1987;14(4):225-34.

2. Feldmann I, Lundström F, Peck S. Occlusal changes from adolescence to adulthood in untreated patients with Class II Division 1 deep bite malocclusion. Angle Orthod. 1999;69(1):33-8.

3. McNamara JA Jr. Components of Class II malocclusion in children 8-10 years of age. Angle Orthod. 1988;51(3):177-202.

4. Ngan PW, Byczek E, Scheick J. Longitudinal evaluation of growth changes in Class II division 1 subjects. Semin Orthod. 1997;3(4):222-31.

5. Vale DMV, Martins DR. Avaliação cefalométrica das estruturas dentoesqueléticas em jovens portadores de Classe II, divisão 1, brasileiros, leucodermas e de origem mediterrânea. Ortodontia. 1987;20(1-2):5-17.

6. Pancherz H. Treatment of class II malocclusions by jumping the bite with the Herbst appliance. A cephalometric investigation. Am J Orthod. 1979;76(4):423-42.

7. Hansen K, Pancherz H, Hägg U. Long-term effects of the Herbst appliance in relation to the treatment growth period: a cephalometric study. Eur J Orthod. 1991;13(6):471-81.

8. Konik M, Pancherz H, Hansen K. The mechanics of Class II corrections in late Herbst treatment. Am J Orthod Dentofacial Orthop. 1997;112(1):87-91.

9. Pancherz H. The Herbst appliance – its biologic effects and clinical use. Am J Orthod. 1985;87(1):1-20.

10. Pancherz H. The mechanism of Class II correction in Herbst appliance treatment. A cephalometric investigation. Am J Orthod. 1982;82(2):104-13.

11. Croft RS, Buschang PH, English JD, Meyer R. A cephalometric and tomographic evaluation of Herbst treatment in the mixed dentition. Am J Orthod Dentofacial Orthop. 1999;116(4):435-43.

12. Franchi L, Baccetti T, McNamara JA Jr. Treatment and posttreatment effects of acrylic splint Herbst appliance therapy. Am J Orthod Dentofacial Orthop. 1999;115(4):429-38.

13. Hansen K. Treatment and post treatment effects of the Herbst appliance on the dental arches and arch relationships. Semin Orthod. 2003;9(1):67-73.

14. McNamara JA Jr, Howe RP, Dischinger TG. A comparison of the Herbst and Fränkel appliances in the treatment of Class II malocclusion. Am J Orthod Dentofacial Orthop. 1990;98(2):134-44.

15. Omblus J, Malmgren O, Pancherz H, Hägg U, Hansen K. Long-term effects of Class II correction in Herbst and Bass therapy. Eur J Orthod. 1997;19(2):185-93.

16. Sidhu MS, Kharbanda OP, Sidhu SS. Cephalometric analysis of changes produced by a modified Herbst appliance in the treatment of Class II division 1 malocclusion. Br J Orthod. 1995;22(1):1-12.

17. Valant JR, Sinclair PM. Treatment effects of the Herbst appliance. Am J Orthod Dentofacial Orthop. 1989;95(2):138-47.

18. Windmiller EC. The acrylic-splint Herbst appliance: a cephalometric evaluation. Am J Orthod Dentofacial Orthop. 1993;104(1):73-84.

19. Wong GW, So LL, Hägg U. A comparative study of sagittal correction with the Herbst appliance in two different ethnic groups. Eur J Orthod. 1997;19(2):195-204.

20. Pangrazio-Kulbersh V, Berger JL, Chermak DS, Kaczynski R, Simon ES, Haerian A. Treatment effects of the mandibular anterior repositioning appliance on patients with Class II malocclusion. Am J Orthod Dentofacial Orthop. 2003;123(3):286-95.

21. Pancherz H, Anehus-Pancherz M. The headgear effect of the Herbst appliance: a cephalometric long-term study. Am J Orthod Dentofacial Orthop. 1993;103(6):510-20.

22. Lai M, McNamara JA Jr. An evaluation of two-Phase treatment with the Herbst appliance and preadjusted edgewise therapy. Semin Orthod. 1998;4(1):46-58.

23. Pancherz H. The nature of Class II relapse after Herbst appliance treatment: a cephalometric long-term investigation. Am J Orthod Dentofacial Orthop. 1991;100(3):220-33.

24. Franchi L, Contardo L, Primozic J, Perinetti G. Clinical alteration of mandibular growth: what we know after 40 years. In: McNamara JA Jr, ed. The 40th Moyers Symposium: Looking back... Looking forward. Craniofacial Growth Series. Center for Human Growth and Development, University of Michigan; 2014, p.263-85.

25. Batista KBSL, Thiruvenkatachari B, Harrison JE, O'Brien KD. Orthodontic treatment for prominent upper front teeth (Class II malocclusion) in children and adolescents. Cochrane Database Syst Rev. 2018 Mar;13(3):CD003452. doi: 10.1002/14651858.CD003452.pub4. PMID: 29534303; PMCID: PMC6494411.

26. Silva Filho OG, Ozawa TO, Ferrari Júnior FM, Aiello CA. Aparelho de Herbst: variação para uso na dentadura mista. Rev Dent Press Ortod Ortop Facial. 2000;5(5):58-67.

27. Burstone CJ, Koenig HA. Optimizing anterior and canine retraction. Am J Orthod. 1976 Jul;70(1):1-19.

28. Atresh A, Cevidanes LHS, Yatabe M, Muniz L, Nguyen T, Larson B, et al. Three-dimensional treatment outcomes in Class II patients with different vertical facial patterns treated with the Herbst appliance. Am J Orthod. Dentofacial Orthop. 2018;154:238-48.

29. Obijou C, Pancherz H. Herbst appliance treatment of Class II, division 2 malocclusions. Am J Orthod. Dentofacial Orthop. 1997;112:287-91.

30. Pancherz H. The effects, limitations, and long-term dentofacial adaptation to treatment with the Herbst appliance. Semin Orthod. 1997 Dec;3(4):232-43.

31. Wieslander L. Intensive treatment of severe Class II malocclusions with a headgear-Herbst appliance in the early mixed dentition. Am J Orthod. 1984;86(1):1-13.

32. Rodrigues GT. Angle's Class II division 1 associated to mandibular retrusion and skeletal open bite: a 5-year post-orthodontic/orthopedic treatment follow-up. Dental Press J Orthod. 2017 Sept-Oct;22(5):98-112.

33. Rédua RB. Different approaches to the treatment of skeletal Class II malocclusion during growth: Bionator versus extraoral appliance. Dental Press J Orthod. 2020 Mar-Apr;25(2):69-85.

Dental Press Journal of
ORTHODONTICS

Volume 26 - Number 2 - Online

SPECIAL ARTICLE

https://doi.org/10.1590/2177-6709.26.2.e21spe2

A reflection on the role of women in Science, Dentistry and Brazilian Orthodontics

Cátia Cardoso Abdo **QUINTÃO**[1] ✉

https://orcid.org/0000-0003-4627-8190

Luísa Schubach da Costa **BARRETO**[2]

https://orcid.org/0000-0002-9363-9772

Luciane Macedo de **MENEZES**[3]

https://orcid.org/0000-0002-8188-9803

Submitted: February 17, 2021 • **Revised and accepted:** March 8, 2021

✉ catiacaq@gmail.com

How to cite: Quintão CCA, Barreto LSC, Menezes LM. A reflection on the role of women in Science, Dentistry and Brazilian Orthodontics. Dental Press J Orthod. 2021;26(2):e21spe2.

(1,2) Universidade do Estado do Rio de Janeiro, Departamento de Ortodontia (Rio de Janeiro/RJ, Brazil). (3) Pontifícia Universidade Católica do Rio Grande do Sul, Departamento de Ortodontia (Porto Alegre/RS, Brazil).

ABSTRACT

Introduction: This paper reviews the history of women scientists in the 'Western world', whilst highlighting the persistent socio-structural issues that have led to the hiding and masking of the participation of women in Science. Further, a reflection is made of the situation of Dentistry, specifically in the field of Orthodontics in Brazil. The difference between genders is discussed, with the intention to map the progress of women in management and leadership positions, in both the academic and professional fields.

Description: In Brazil, within Dentistry and Orthodontics, despite being in a numerical majority, women are still underrepresented in the area of professional leadership. This is true for Research Groups and Research Productivity; an example being the relatively low authorship of publications in a Brazilian journal of Orthodontics. They are also underrepresented as lead presenters at professional meetings, whilst there are also few female Presidents of professional organizations and associations.

Conclusion: Despite being in a numerical majority, it is also important that women act in a more co-ordinated and consistent manner to achieve greater representation in these areas. The necessary changes in the structure in order to achieve this are not only of women and for women, but they must also involve the whole of society so that leadership, rights and duties are equally distributed between the genders.

Keywords: Dentists women. Orthodontics. Education. History of females in Sciences. Leadership.

RESUMO

Objetivo: Este estudo objetivou resgatar a história de mulheres cientistas nos principais períodos históricos do mundo ocidental, para realçar a questão socioestrutural persistente que "invisibiliza" e mascara a participação das mulheres na Ciência. A partir disso, realizou-se uma reflexão sobre a situação da Odontologia, especificamente na área de Ortodontia no Brasil, no que tange à diferença de gêneros, com a finalidade de mapear a atuação das mulheres nos cargos de gestão e liderança nos âmbitos acadêmico e profissional.

Descrição: No Brasil, na área de Odontologia e Ortodontia, apesar de serem maioria numérica, as mulheres ainda são minoria na liderança de Grupos de Pesquisa, Produtividade em Pesquisa, na autoria de artigos em um periódico nacional da área de Ortodontia, palestrantes de congressos e na presidência de Associações de Classe.

Conclusão: Apesar de apresentar maioria numérica, é importante que as mulheres atuem de maneira mais consistente. As mudanças necessárias na estrutura não são apenas da mulher e para a mulher, mas devem envolver toda a sociedade para que direitos e deveres sejam distribuídos de forma igualitária entre os sexos.

Palavras-chave: Odontólogas. Ortodontia. Educação. História da mulher na Ciência. Liderança.

INTRODUCTION

Studies analyzing the participation of women in the history of Science are a relatively recent occurence.[1] Certainly, women have actively contributed to the progress of Science, in several fields, in the various periods of Western history.[1,2]

Due to social structure and concepts imposed by society, their names were often not widely known. Commonly they remained in the shadow of a brother, husband or male co-worker who received the credit for the work. This explains, in part, why so few women have been recognized amongst the ranks of the great scientists. Certainly, historically, there was no shortage of women scientists, but many have been "forgotten"[2]. Since the research history has been predominantly recorded by men, women have been made almost "invisible". This was an issue that was particularly identified after the 1960s. This problem also appears to have occurred in the academic area, where the female presence was largely restricted to a supporting role, as conditioned by the ideology and social structure of the time — it was part of the culture.[1] However, latterly reviews historians have revealed that women did have a very relevant role in Science[3]. If one revisits history, women can be credited with many of the advances in early agriculture, over the period of 8000 to 4000 years BC (prehistoric period), see Table 1. Women can also be identified amongst the first pharmacologists, discovering, by observation, attempt and experimentation, the

Table 1: History periods and events that landmarked them.

Period	Prehistory	Antique	Middle Ages	Modern Age	Contemporary Age
Dates	Until 4000 BC	From 4000 BC to 476	From 476 to 1453	From 1453 to 1789	From 1789 to the present day
Landmark events	Origin of the human species	Invention of writing	Fall of the Roman Empire	Fall of Constantinople	French Revolution

various therapeutic effects of plants. The knowledge accumulated over millennia constituted almost the entire pharmacopoeia until the advent of therapeutic chemistry.[2]

In Antique period, women carried an essential part of scientific and technical progress. Certain periods were marked by cults and legends, in which women played a remarkable role as goddesses and figures associated with alchemy and agriculture, which, not by chance, symbolized fertility. The first names of female 'scientists' recorded in history are from Assyria and Egypt. However, it was in Mesopotamia that women had some autonomy, with the possibility of owning their own lands, businesses whilst occupying important functions such as magistrates. However, the scientific work of ancient Greece was largely reported by the misogynist vision of Aristotle, for whom women were inferior on the spiritual plane, reporting that they had a smaller brain and even suggesting they had a different number of teeth in comparison with men. However, not all Greek philosophers were misogynistic in their outlook. Socrates and Plato accepted intellectual equality and pleaded for women to receive the same education as men. In the schools of Pythagoras (570-495 BC),

which focused on the study of Mathematics, Astronomy, Natural Sciences and Philosophy, women were admitted. In Athens, Plato continued the Pythagorean tradition, accepting women in his classrooms, yet due to Athenian laws, they had to dress as men. Also, in Greek cities, women practiced Medicine, but over time they were limited to the practice of Gynecology. In Rome, women benefited from a relatively favorable status compared to Athenians, where since 450 BC the girls were reported to have received a basic education, learning to read, write and perform mathematics. Also, female doctors were considered equal to their male colleagues, a unique situation in history, which would only occur again in the 20th century.[2]

In the middle ages, the repression of women in the intellectual field worsened with the growth of universities and their monopoly over knowledge. The rediscovery of Aristotle's thoughts further impaired the situation. The growth of cities, formation of States and the strengthening of the Church led to the proliferation of urban schools in the 12th century, the organization of universities in the 13th century, and the creation and diversification of professions in the 14th century. In the 13th century, generally, women were left out of places where knowledge was diffused, i.e., schools and universities. This was a particular time for intellectuals, since knowledge became a source of social ascension, wealth and consideration. Misogyny was a structural component of the culture of the church and general

social environment. Italy continued to be an exception to this rule.[2] At the onset of the 15th century, in France, the right to education had become the primary demand of women, based on the literary works of Christine de Pizan (*Querelle des Femmes* and *La Cité des Dames*, 1405)[4], who put the question of women's education at the center of this debate, against the accepted notion of their physical, intellectual and moral weakness (Fig 1). Christine stated that "if girls received the same education as boys and if they were methodically taught sciences, they would learn and understand the difficulties of all arts and all sciences

Figure 1: A) Representation of a female philosopher in ancient Greece. **B)** Illustration of Christine de Pizan, author of literary works that praise female education. Available at: https://mythicscribes.com/history/christine-de-pizan/.

as well as them" (men). For the first time, a woman dared to defy the general misogyny, giving strength to the debate, with participation of women and men from several European countries (France, England, Italy, Denmark).[5]

At the beginning of the Modern Age, a new market opened, grew and fragmented into dozens of new professions, thanks to the invention of the press in the middle of the 15th century.[2] The Scientific Revolution raised an unexpected enthusiasm for the whole subject and the related experimental method, with a multiplication of courses on these themes. Women actively participated in this movement, making important contributions, although it often generated criticism. The notion that the perceived defects assigned to women were due to the lack of education they received was gaining more credence and followers.[5] After the 17th century, with the advent of industrial capitalism, the social responsibility of men for production and women for reproduction[6] became more evident. However, in France and England, the female society, aristocratic or bourgeois, fell in love with the sciences, discussed the latest inventions, learned mathematics and practiced Experimental Science. Women contributed significantly to the spread of new scientific and philosophical discoveries. Excluded from universities and academic institutions, women of the elites were assiduous in taking private courses, read a lot and created discussion meetings, which aided the intellectual diffusion of France abroad.[2] After 1760, the need for an educational

reform was recognized. Female education was then allowed, in the father's home or in some institutions.[5] However, outside the family environment, all intellectual activity was discouraged because it "contradicted the biological destiny of women". Even so, in the period of the French Revolution, the philosopher Condorcet (1743-1794) unsuccessfully advocated mixed teaching based on the equality between genders. However, education plans continued to confine women to the household knowledge as necessary for family economics, in other words, reading, writing and some notions of arithmetic. For women from the wealthier classes, recreational arts such as Music, Singing and Dancing were included. Thus, excluded from all political activities, women could only achieve a primary education.[5]

Women from the 17th and 18th centuries participated in various scientific or technical activities. However, with a few exceptions, only a limited number managed to study in any depth. During the time of the Enlightenment (1715-1789), the important role of women in motherhood was identified, thus the role of the mother in the education and training of children became much more valued. Some women, that belonged to the noble or bourgeois classes, had the opportunity to receive a good education. However, generally they were relegated to the role of assistants or collaborators to well-known scientists. Notwithstanding, there were women who advocated their right to education and access to the same intellectual activities as men.[5]

In the Contemporary Age, after the French Revolution, Western democracies emerged, whose essence was equality. Philosophers of the time addressed the issue of gender by trying to explain, by reason and thought, a paradox: why human beings are equal to each other and unequal at the same time. The greatest philosophers, who based their works on democracy, the State of law, human rights and liberalism, were associated, almost without exception, with the idea that women were inferior to men, which would justify their submission to their father and/or husband. They argued that biological difference would explain the women's inability to participate equally to men in political and intellectual life. However, in reality there was a need to move woman away from education, so that they would not become a threat to the perceived roles of men[2]. Thus, during this period, the vast majority of women were illiterate. Until the onset of the 19th century, only a minority, from the aristocracy and upper bourgeoisie had access to further education, although these women could serve as example for many others.[2] In the 19th century, Science became more professional and also became a competitive activity, with the need for qualified people pursuing Science within the context of certain rules of conduct and hierarchy. Once again, women experienced great difficulties in entering the elitist and stratified institutions created, facing new problems, new forms of exclusion and consequently needing to adopt new strategies.[5] Despite the advances in the intellectual condition of some

women over the 17th and 18th centuries, there was a general stagnation in the 19th century, based on recurring arguments that women were not made for Science, due to their nature and perceived roles within that society.[2]

In the 19th century, significant changes occurred in the production process and organization of activities, with the consolidation of capitalism, which ended up expanding the need for female work.[6] In the 20th century, the advent of the two World Wars also facilitated the insertion of female labor, due to the need to replace the contingent of recruited male workers. However, women were exploited and subjected to subhuman working conditions, with long hours and receiving much lower wages than men. The ideological rationale for this, at the time, was that women had or should have someone to support them. However, socially, the woman was still responsible for the family dynamics and all duties related to it. Therefore, emancipation was only partial, resulting in the accumulation of double working hours, causing a significant disadvantage compared to men in the labor market.[6]

Some misogynistic views persist into the 21st century. In 2005, Larry Summers, Dean of Harvard University, pointed out that the discrepancy could be related to the innate abilities of men compared to women, i.e., males would have a more naturally acquired aptitude for Science than females,[3,6] in other words,

biological differences might explain the reduced success of women in Science. Such views by certain academic leaders can only corroborate any existing prejudices and untruths that make difficulties for women pursuing a career in the Sciences.

Currently, women work in nearly all fields of professional activity, but there is a concentration in intermediate positions, whilst executive and management positions are still mostly occupied by men.[6] The change in this scenario started in the second half of the 20th century, with the increased need for human resources for Science. In addition, women's liberation movements and the struggle for equal rights between men and women allowed them access to scientific education and careers traditionally occupied by men.[7] Only in the second half of the 1970s and throughout the 1980s, the debate on equality and difference became the center of discussions. Cultural difference, female culture, female experience and the recognition of cultural gender diversity started to be discussed.[8] Currently, in Western societies, men and women are moving away from stereotyped gender models and developing new forms of subjectivity, free from the divisions presented by society.[8]

THE SCENARIO OF WOMEN IN BRAZIL IN THE 19TH AND 20TH CENTURIES

For nearly 450 years, there was a significant difference in schooling between Brazilian women and men, due to the prevailing social structure at the time. It is important to revisit the past to understand the historical context of the existing social structure and its influence on the role of women in society.

In the period between the end of the Second Empire (1840-1889) and the early 1920s, the city of Rio de Janeiro, the capital and most important city in Brazil at that time, was site to several movements, due to political and social dissatisfaction. The lower classes of the population were illiterate, with little political participation and no voting rights. The same was true for women, who were ultimately considered irrational, submissive and unable to discern public issues. Legally, they were subject to the father or husband, having no individual rights, freedom of conscience, thought, expression, religion, as well as mobility, work and management over patrimonial and heritage resources.[9]

During the Old Republic (1889 to 1930) women were considered different from men, not only in physical characteristics, but also in moral and psychological terms. Thus, women were seen as unstable and subjected to interventions from the environment, which could alter their normal development,

hindering their primary function, which was considered to be reproduction. Cultural activities, education or work were seen as "harmful influences" for women. Medical professionals tried to highlight the differences between men and women, emphasizing their reproductive function[9]. Men were the holders of intelligence, reasoning and physical strength, with the power to change society, leading in Science and Politics. Women were responsible for motherhood and home. Thus, their education should emphasize hygiene, character and was based on the principles of moral, social and civic values, according to the Republican speech.[9] The educational guidelines for boys and girls differed in content and they were not allowed to study together. According to the General Law of 1827, which regulated primary education in the country, girls only had access to the first level of education[9]. Over time, the need to educate future mothers, due to the project of modernization of the society and family, women gained greater access to education, increasing the need for more teachers for girls. Teaching would not subvert the role of women; rather, it could expand it. From then on, teaching began to be considered a typically female activity. The incompatibility of female professionalization with marriage and motherhood was one of the most persistent social constructions, and justified the lower wages offered to women.[9] Speeches on women's morals and bodies were based on religion, even after the advent of the Republic, with separation of Church and State, which became secular.

Thus, the Medicine, Church and society legitimized a model in which marriage was seen as the social ideal, while work outside home was considered inappropriate for women.[9]

In various censuses, it was possible to observe the participation of women in the labor market. The 1890 Census provided little information on female labor, since it made no reference to activities related to the domestic field (such as washerwomen, seamstresses, embroiderers, cooks), which were mostly performed by poor women. In addition, in some categories of work there was no distinction by gender, such as in agriculture and industry. In the 1906 Census, it was found that 80.34% of working women were connected to domestic services. Also, in the 1920 Census, most women remained in the domestic service category (82.08%). In industry, the female participation continued to be higher in the clothing (62.18%) and textile sectors (39.26%). At that time, women were also present in the service sector (post offices and telegraphs - 31.92%) and then represented 81.20% of the total number of primary schoolteachers.[9]

In the Vargas Era (1930-1945) women were considered instruments to transform the country's population, since they played the "female" functions that involved taking care of home, motherhood and caring for the family's well-being. These functions were considered essential for the construction of a healthy, disciplined and productive population.[10] At the same time, there was an awakening to the issues of female emancipation and

the achievement of labor and political rights, such as the right to vote. As an example of these changes, separation is mentioned, which was instituted in the Civil Code in 1942, establishing the separation without dissolving the marriage bond, yet this condition was not socially well accepted.[11] In 1943, the Brazilian law granted permission for married women to work outside home without the "express authorization of the husband".[11] The country was blooming, industrializing and in need of labor force, and women began to take up new work fronts. Conversely, their presence was advocated exclusively at home, as housewives and mothers.[10] However, institutional and social changes continued to occur.

In the 1960s, the feminist movement gained strength. In 1962, twenty years after the introduction of separation, the Statute of Married Women came into force, which recognized her condition as one of "companion, consort, collaborator of the family's responsibilities, responsible for ensuring its material and moral direction". This was undoubtedly an advance in relation to the Civil Code of 1916, which considered women "incapable".[11] Also, after the 1960s, women in Brazil started to have access to more efficient contraceptive means (birth control pill, in 1962). Educational possibilities have also increased, with repercussions to the family relationships. In 1961, the Law of Brazilian Education Guidelines and Bases assured the equivalence of high school courses, allowing students in the teaching profession ("Escola Normal") to compete for places in higher education.[11]

In the 1960s and 1970s, Brazilian women changed their values and ideals. There was an increase in women's participation in the labor market and also a struggle for growth and professional recognition. Women had greater access to formal education and achieved the right to decide whether to become a mother. In 1977, divorce was instituted and also the possibility of establishing other affective relationships, socially recognized. Thus, after the 1970s, women of middle and upper classes could envision a professional future for their daughters, earning their own money, with life horizons beyond marriage, while simultaneously they began to occupy a more egalitarian position in relation to the husband.[11]

In the 1980s, Brazilian women changed their role in the family, society and the labor market. The Federal Constitution of 1988 provided relevant achievements[11] because it expanded individual and social rights and consolidated women's citizenship in the public space and family life. This assured rights in the fields of health (including sexual and reproductive health); safety; education; land ownership and access to housing; work, income, social security and access to civil and political rights.[12] In the last decades of the 20th century and early 21st century, women reached important parts of the labor market, achieved greater schooling, managed to expand control over their sexuality and fertility, but also increased their working hours. However, despite all advances in recent decades, inequality is

still evident, especially when comparing average wages, which are about 30% lower compared to men.[11] Despite persistent social differences between men and women, families tend to form a more egalitarian relationship between partners, since both contribute financially to the maintenance of home and its members. This change empowered women within their families, breaking the old cycle of dependence and subordination. Following the changes in society and contributing, in turn, to change society itself, the "modern conjugal family" as proposed in the first half of the 20th century is no longer the predominant reference.[11] New family arrangements have emerged (single parents, reunited families, homosexual relationships). There was a transformation of families, a drop in birth rate, an increase in marriages and remarriages of the most varied types. Family unions and bonds have emerged, which reflect the affective relationships, and the Brazilian conjugal society is driven by loving relationships and individual satisfaction.[11]

THE SCENARIO OF DENTISTRY AND ORTHODONTICS IN BRAZIL

Until the onset of last century, it would be impossible to think of a scenario in which women would form a majority in the field of Dentistry in Brazil. Even at the end of the 19th century, professional practice was performed mainly by dentists not formally trained, due to the lack of Dentistry Courses.[13] This occurred until establishment of the first course, officially created in Brazil

by a decree of the Imperial Government, signed by D. Pedro II, on October 25, 1884.[14] Thus, at the end of the 19th century, there were three Dentistry Courses in Brazil: at the Federal University of Rio de Janeiro, Federal University of Bahia and Federal University of Rio Grande do Sul,[15] which were constituted almost exclusively by men. Dental practice by women was rare until the end of the Empire. As in other countries, women working in this field were basically limited to daughters, wives or widows of dentists (lay women who had achieved the profession from another practitioner).[13] Few women in this period entered regular courses.

The teaching of Dentistry in São Paulo began in 1902, with female students from the start. From 1903 to 1926, 221 women (19.23% of the total graduates) and 928 men graduated from the current School of Dentistry at the University of São Paulo.[13] The care of ladies and children patients was an option for many female dentists. Some had their own offices and others shared spaces with family and colleagues.[13] At that time, a movement to regulate the profession was initiated in São Paulo. Thus, to continue their activities, non-graduated dental practitioners should undergo a qualification exam to a commission of graduates. In this process, in the state of São Paulo, 172 men and nine women who were licensed dentists enrolled in the Health Service between 1900 and 1925.[13]

Dentistry courses in Brazil have had an exponential growth since their establishment[15]. Women were in a minority until the 1980s, when dental schools began to train more women than men, with increasing feminization of the profession.[13] The increase in the number of women in undergraduate and graduate courses, either as students, professors or researchers, as well as their access as scholars of research programs, have undoubtedly contributed to the inclusion of woman in all areas of Science and Technology agencies.[12]

Until the middle of the 20th century, there were 24 Dentistry courses in Brazil, half of them concentrated in the Southeast region.[15] There was a more intense expansion in the number of Dentistry courses since 1961, with the regulation of the Law of Brazilian Education Guidelines and Bases, which increased educational opportunities, creating financial and legal support for the private sector in the field of education, whilst promoting a great expansion of private education network in the country.[15] The so-called "Renewal of the Brazilian University" movement (1968) expanded the number of Dentistry courses, opening higher education to private institutions for profit, which led to a change in the standards of higher education. The Teaching-Research-Extension triad was weakened in some institutions, prioritizing only Teaching, opening the Education market to institutions with a business profile. This expansion led to a four-fold increase in the number of Dentistry courses in Brazil until 1996, when, among 104 existing courses, 60 were offered in private institutions.[15]

Currently, there are 544 authorized Dentistry courses in Brazil, being the country with the highest absolute number of Dentistry courses in the world, running the risk of collapse due to the abundance of dentists in the job market.[15] The greatest concentration of courses is still in the Southeast region (36%), followed by the Northeast (29%), South (16%), Central West (10%) and North (9%).[15]

The disorganized expansion also occurred in postgraduate courses in the field of Orthodontics: in the 1950s there were 2 accredited courses, and in 2009 there were 309 courses[16] (representing 1/3 of all Dentistry Specialization courses in Brazil). Thus, Brazil has a total of 344,041 dentists registered in the Federal Dental Council, almost 10% of which, i.e., 30,266, are orthodontists/functional orthopedists, and almost 60% of these (18,066) are women.

Compared to other countries as the United States and Canada, the uncontrolled growth in the number of postgraduate courses in Orthodontics in Brazil is quite evident. The United States has 67 Postgraduate courses in Orthodontics and Canada has 6, accredited by the American Commission on Dental Accreditation (CODA) and the Commission on Dental Accreditation of Canada (CDAC), according to data obtained from the American Orthodontics Association (AAO)[17] website (Table 2). Analyzing the ratio between number of inhabitants

and number of courses in Orthodontics in United States, Canada and Brazil, it is observed that, for the former, this ratio is 4.97 million, for Canada 6.26 million, while for Brazil, in 2009, with a population of 193.9 million, this index would be 627.5 thousand inhabitants per postgraduate course in Orthodontics.

Orthodontics was the first dental specialty to be recognized as such in June 1900. Edward Hartley Angle was elected the first president of the American Society of Orthodontists. The first postgraduate courses in Orthodontics in North American universities emerged in 1922, at the Universities of New York and Columbia. In Brazil, the first specialization course in Orthodontics started in 1951, at São Paulo Dental Association (APCD), functioning until 1955.[18] The first specialization course in Orthodontics in a Brazilian university was initiated in 1959 at the School of Dentistry at the Federal University of Rio de Janeiro (UFRJ). In 1974 the course was raised to the MSc level and, in 1981, the PhD course was initiated. In 1962, at the Piracicaba School of Dentistry (currently belonging to UNICAMP), the second specialist course in Orthodontics was initiated, recognized

Table 2: Number and coordination (by gender) of Postgraduate Courses in Orthodontics in the United States and Canada. Source: American Association of Orthodontists[17], 2020.

Country	Coordinator man	Coordinator woman	Total courses
USA	55 (81.0%)	13 (19.0%)	67
Canada	5 (83.4%)	1 (16.6%)	6

as a MSc degree in 1974, and a PhD degree in 1983. In 1966, the course in Orthodontics was established at the School of Dentistry of the University of São Paulo (USP), which in 1974 was accredited as a MSc. At Bauru School of Dentistry, University of São Paulo (FOB-USP), in 1973, the course in Orthodontics was started, with an MSc degree in 1981 and a PhD course was commenced in 1982 and recognized in 1989.[18] Thus, in a time span of 14 years (1959–1973), there were four graduate courses in Orthodontics in Brazil.[18] In the last decade (2010-2020), 534 specialization courses in Orthodontics were registered in Brazil, according to the Federal Dental Council,[19] as shown in Table 3, showing the exaggerated increase in the number of postgraduate courses in Orthodontics in the country.

Analyzing the history of 60 years of the oldest postgraduate course in Orthodontics at a Brazilian university,[21] the UFRJ, it was observed that, among all students graduating from the MSc Course (Fig 2), 52.7% are males and 47.3%, females. Until the fifth group (1966/1968) the composition was exclusively of men. From then on, until the 27th group (1991/1993), there was predominance of males, except for the 11th group (1975/1977). After 2010, there has been predominance of women in nearly all groups. Analyzing the total number of students graduating from the PhD Course at UFRJ (Fig 3), 52.2% are males and 47.8%, females.

Table 3: Number of Orthodontists; Specialist Courses in Orthodontics registered in the CFO (2010 to 2020) and Courses Coordinators according to sex (Source: data extracted from material provided by CFO[19] and total of orthodontists registered in the CFO by region[20]).

Region of Brazil	Number of orthodontics	Number of courses	Courses coordinated by men	Courses coordinated by women	Courses without coordinator registration
North	1,513	32	22	7	3
Northeast	2,564	64	40	21	3
Midwest	3,085	50	28	13	9
Southeast	14,850	252	161	74	17
South	7,272	136	107	23	6
Total	**29,284**	**534**	**358**	**138**	**38**

For both MSc and PhD courses, there is predominance of men at their beginning (1960s and 1980s), and currently a predominance of women.

The greater presence of women in the Academy in recent years may have facilitated the access and incorporation of women to the staff of Brazilian universities[7]. It seems that this phenomenon has been occurring with a gradual increase in the number of women in graduate courses. Due to their insertion in the academic career, many universities now have women in their staff. Thus, though still distant in relation to gender equality, they have come very close to men, i.e., the situation has been balancing. It should be noted that the insertion of women into the Academy began a long time after men. Therefore, when

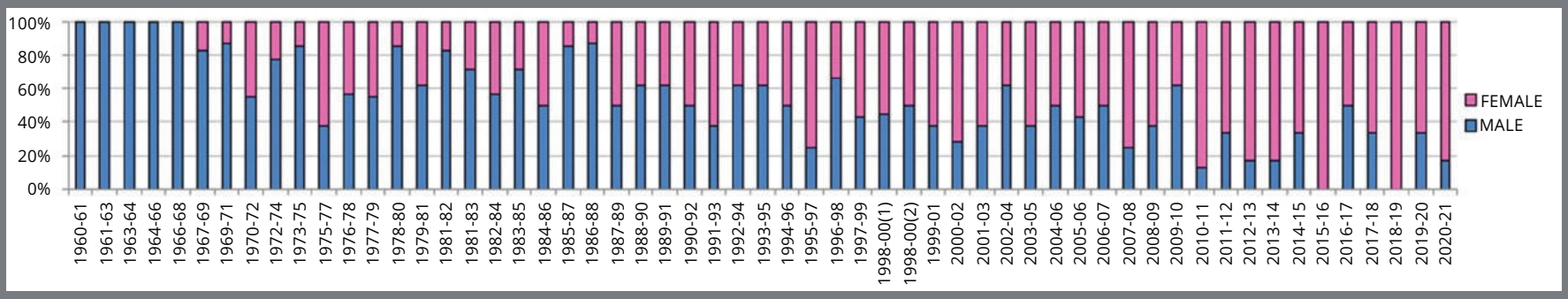


Figure 2: Distribution of Masters students in Orthodontics, UFRJ (from 1960 to 2020), by sex. Source: Archives of the XIX Alumni Meeting of UFRJ[21], 2019.

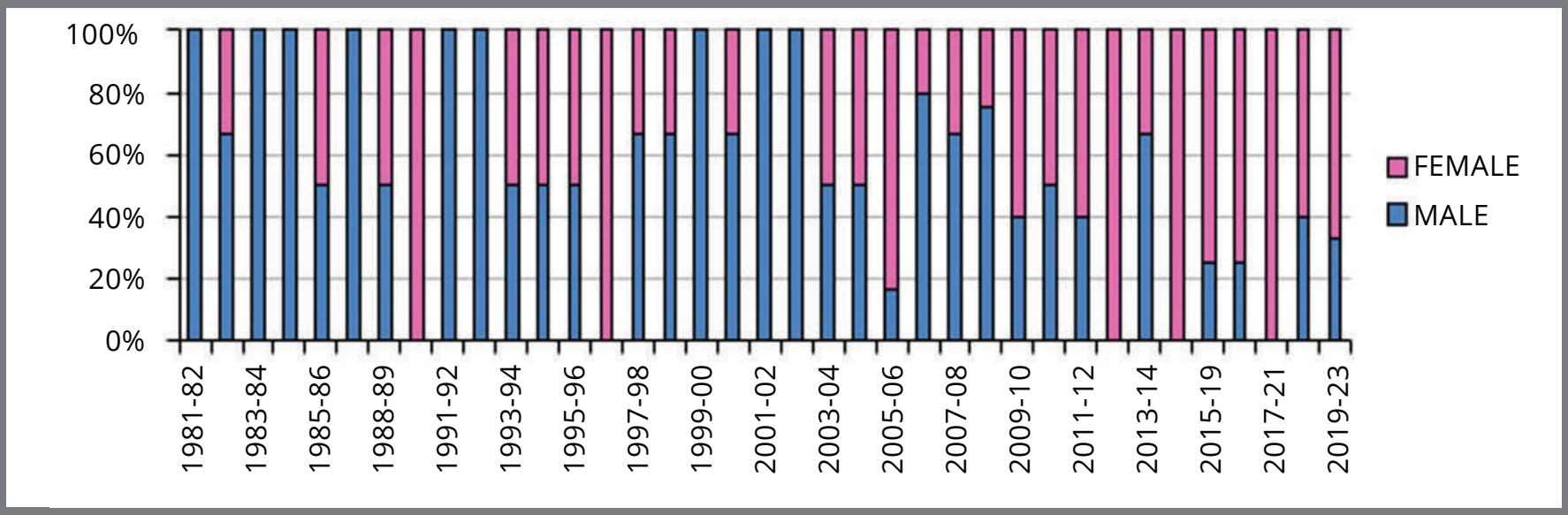


Figure 3: Distribution of PhD students in Orthodontics at UFRJ (1981 to 2020), by sex.
Source: Archives of the XIX Alumni Meeting of UFRJ[21], 2019.

analyzing the progress and evolution of female participation over time, it is noticed that they are occupying spaces in an increasing and consistent manner.

Analyzing postgraduate courses in general, in 2019 women represented about 54% of PhD students in Brazil, indicating an increase of 10% in the last two decades. This number was similar to that of developed countries, such as the United States, where in 2017 women obtained 53% of PhD degrees awarded in the country. However, in Brazil, alike the rest of the world,

this female participation varies a lot according to the field of knowledge.[22] Women form a majority in Life and Health Sciences (more than 60%), while in Mathematics and Computer Science they represent less than 25%.[22]

Analyzing the Graduate Courses in Dentistry in Brazil considered of an excellent standard (Scores 5, 6 and 7, Capes/2017, scores range from 1 to 7), it was observed that, among 22 courses, 14 are coordinated by women (63,64%) and 8 by men (3,36%) (Table 4). Possibly, the greater number of female students in undergraduate courses and graduate programs enabled their greater demand for positions of higher hierarchy in the system.[7]

With the high number of female orthodontists in Brazil, how are they distributed in management, prominence or leadership positions in the academic environment?

Considering the Coordination of Postgraduate Courses in Orthodontics in Brazil, specialist level, in the last decade, the Brazilian Federal Dental Council (CFO) registered 534 courses, among which 358 were coordinated by men and 138, by women (38 are unregistered) (Table 3).

Analyzing data presented by the AAO related to the American and the Canadian Postgraduate Courses in Orthodontics (Table 2), it was observed that, among 74 courses registered until 2020, 14 are coordinated by women (18.9%) and 60 (81.1%), by men.

Table 4: Coordinators of the Graduate Programs in Dentistry, scores 5, 6 and 7 (CAPES).

Score	Coordinator man	Coordinator woman	Total
5	6	7	13
6	2	4	6
7	0	3	3
Total	8 (36.36%)	14 (63.64%)	22

Source: Plataforma Sucupira; Accessed on: January 20, 2021. https://sucupira.capes.gov.br/sucupira/public/consultas/coleta/program/quantitativos/quantitativo Brasileiro.jsf?areaAv

At the beginning of the century, there was a growing trend in the percentage of women taking positions of researchers and leading figures in research groups, indicating a greater insertion of women in the system, not only as students, but in positions of greater recognition and higher hierarchical qualification.[7] Statistics referring to the Brazilian National Council for Scientific and Technological Development (CNPq) research groups revealed a continuous process of approximation between the percentage of men and women researchers: in 1995, women represented 39% of researchers; in 2002, 46%; in 2010 parity was reached between genders.[7] Specifically, in the field of Orthodontics, there is still a smaller number of women leaders of Research Groups or Productivity Researchers of CNPq (Fig 4).

In 2003 it was already observed that the proportion of female scholars increased in different modalities, yet it decreased as the hierarchical level of the scholarship increased, indicating that part of the women who went through the first stages of qualification and training for scientific activities did not continue their careers or did not get peer recognition to achieve scholarships.[7] At this time, women accounted for around 50% of all scholarship modalities (Scientific Initiation, MSc, PhD, Postdoctoral, Research Productivity and Technical Business Development). Only in the last two modalities, the percentage of women was lower than men.[12] In 2019, women represented only 24% of

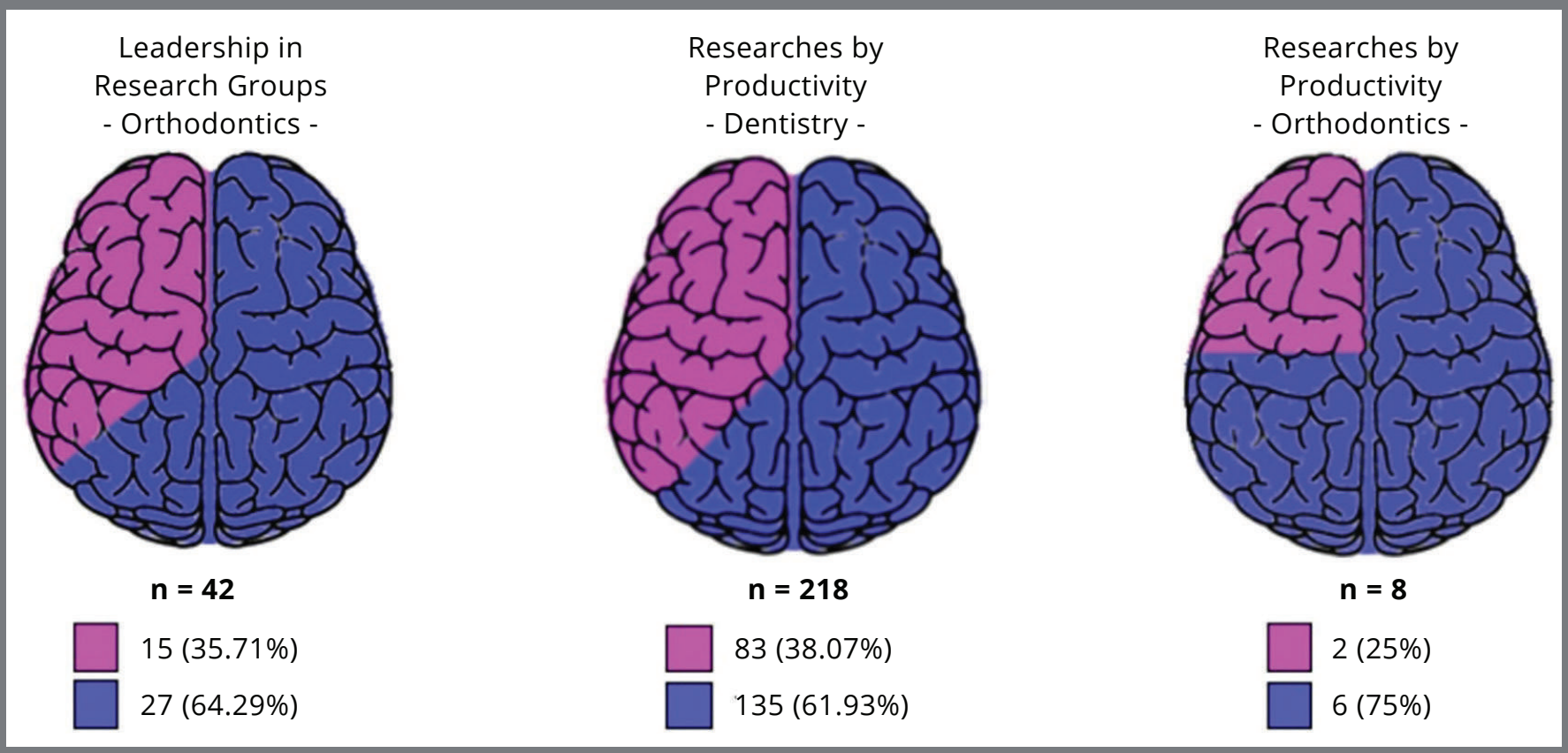


Figure 4: Leadership in Research Groups (Orthodontic**s)** CNPq; and CNPq Productivity Researchers (Dentistry and Orthodontic**s)** (pink color for women; blue color for men). Source: CNPq[23], 2020.

Research Productivity Scholars, considering all fields of knowledge.[22] In the case of Dentistry and also Orthodontics, there is still a predominance of males as Productivity Researchers (CNPq) (Fig 4). Why do women researchers, dentists, and orthodontists, with a high scientific productivity, fundraising capacity, a greater training in human resources and with a higher degree (fundamental requirements to coordinate Graduate Programs of Excellence in Dentistry at Brazilian Universities) not equal the number as Research Productivity Scholars or Leaders in Research Groups? Are women researchers, dentists and orthodontists actually less productive than men, or are there still socio-structural factors involved?

Concerning the publication of scientific papers from all fields of knowledge, Brazilian women exceed the production of men.[22] The impact of the work of men and women is comparable regarding the number of article citations. Between 2008 and 2012, women were already responsible for almost 70% of the total number of publications by Brazilian scientists, one of the highest proportions in the world.[22]

Considering the best ranked Orthodontics journal in Brazil (Dental Press Journal of Orthodontics, DPJO),[24] which presents a high Impact Factor and Cite Score, the scientific production was evaluated in relation to the gender of authors, in the last 10 years. In the period from 2010 to 2020, evaluating all issues

of the journal (6 per year), it was concluded that women presented a lower percentage than men in relation to authorship, both as first and last authors and also in relation to co-authorships (Table 5). The total number of authors (men and women) of DPJO in this decade was 3,238, being 1,956 (60.4%) men and 1,282 (39.5%) women, showing a lower percentage of women authors than revealed for the scientific production in general, namely 70% as mentioned above, for the period from 2008 to 2012. When considering the first author (who defines the executor of the research) the participation of women in the journal varied from 32.92% (2014) to 51.60% (2019). The last authorship (which defines the intellectual supervisor of the investigation) had female representation ranging from 25.58% (2016) to 49.12% (2015). Considering the total number of women in each article, they were also minority — between 36.59% (2013) to 45.58% (2019). Women reached a number close to men as first authors and in the total number of authorships in 2019, falling back in 2020.

The DPJO journal has already had 5 Editors since its onset in 1996, and since 2018 it has a female Chief Editor for the first time in its history.

Aiming to analyze the performance of women in Orthodontics Associations, data from the World Federation of Orthodontists[25] and the Brazilian Orthodontic Association[26] were consulted.

Table 5: Publications from the Dental Press Journal of Orthodontics (2010 to 2020), with total authors per year, distribution of authors according to sex and authorship. Source: Dental Press Journal of Orthodontics[24], 2020.

Journal	Year	Total articles	Total authors (men and women)	First Author	Total of co-authors	Last author	Total authors
DPJO	2020	66	221	26 (39.39%)	41 (37.61%)	14 (29.78%)	81 (36.65%)
	2019	62	204	32 (51.60%)	44 (44.00%)	17 (40.47%)	93 (45.58%)
	2018	61	217	26 (42.62%)	40 (38.46%)	16 (30.76%)	82 (37.78%)
	2017	70	237	26 (37.14%)	48 (40.67%)	16 (32.65%)	90 (37.97%)
	2016	62	218	21 (33.87%)	48 (42.47%)	11 (25.58%)	80 (36.69%)
	2015	82	279	28 (34.14%)	55 (39.28%)	28 (49.12%)	111 (39.78%)
	2014	82	269	27 (32.92%)	66 (51.56%)	20 (33.89%)	113 (42.00%)
	2013	114	440	46 (40.35%)	87 (37.02%)	28 (30.76%)	161 (36.59%)
	2012	127	471	55 (43.30%)	98 (41.35%)	43 (40.18%)	196 (41.61%)
	2011	89	337	39 (43.82%)	76 (44.18%)	27 (35.52%)	142 (42.13%)
	2010	95	345	43 (45.26%)	64 (37.20%)	26 (33.33%)	133 (38.55%)

The World Federation of Orthodontists (WFO)[25] was established on May 15, 1995, with the goal to develop the art and science of Orthodontics. It currently has 109 affiliated entities around the world.

The Brazilian Association of Orthodontics and Facial Orthopedics (ABOR)[26] was established on January 25, 1994, with the aim of gathering regional associations, some of them much older as the Brazilian Orthodontic Society (1955) and Orthodontics Societies of the states of Paraná (1972), Rio Grande do Sul (1975), Espírito Santo (1985) and Minas Gerais (1985).[27] In May 1995, the ABOR joined the WFO, then representing the Brazilian Orthodontics in the international scenario.

The WFO has had 6 presidents since its establishment, all men. Conversely, ABOR also had 6 presidents, being one woman. Currently, of the 22 regional offices of ABOR, 15 are directed by men and 7 by women (Table 6).

The Brazilian Board of Orthodontics (BBO)[28] was created in 2002 due to the need to establish standards of clinical excellence to value the specialty. The evaluations started in 2004 and are made annually, based on the American Board of Orthodontics, with theoretical and clinical case examinations. Orthodontics was a pioneer in the Health area in Brazil to have an examination for the certification of professionals regarding clinical excellence. The proportion of BBO graduates and directors reveals a predominance of males, with 75.51% of graduates and 87.5% of directors composed of men (Fig 5).

Table 6: Composition of WFO[25] and ABOR[26] (National and Regional Boards).

Entities	Total	Presidents	
		Men	Women
WFO (Presidents) (1995-2020)	6	6 (100%)	0 (0%)
ABOR - National Board (1994-2020)	6	5 (83.33)	1 (16.66%)
ABOR - Regional Offices (2020)	22	15 (68.18%)	7 (31.81%)

The ABOR[26] organizes an International Congress every two years with the participation of all 22 Regional Offices, the Brazilian Board of Orthodontics (BBO)[28] and the Brazilian Group of Professors in Orthodontics and Pediatric Dentistry. All presidents of ABOR Congresses in the last 10 years (Table 7) were men. Only in 2022 the ABOR congress will have a woman as president.

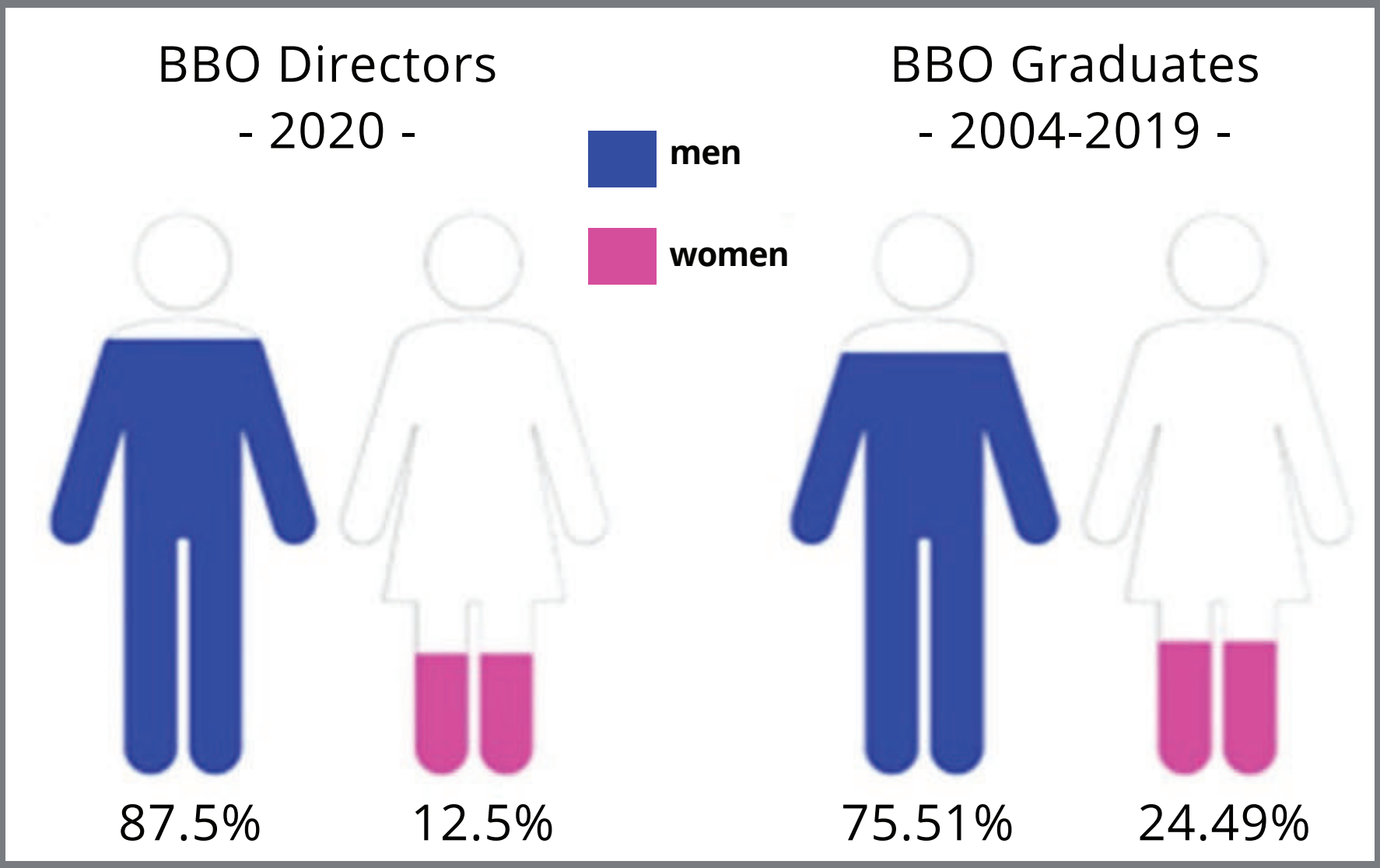
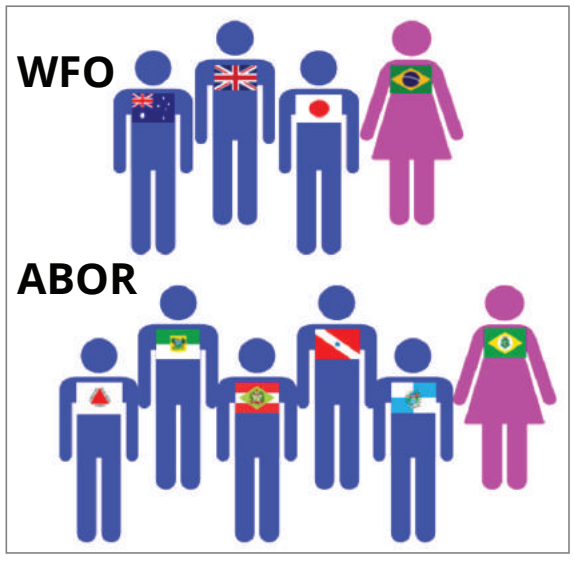


Figure 5: Composition of Directory and Graduates of the Brazilian Board of Orthodontics (BBO) according to sex. Source: BBO,[28] 2020.

The female participation in prominent positions is the result of a personal effort by a few women to break a system structurally constituted by men. Thus, it is important to mention Professor Flavia Artese, from the State University of Rio de Janeiro, who was President of ABOR for two periods (2014-2018). She currently is the Chief-Editor of DPJO, the first woman to compose the Board of Directors of the College of Diplomates of the Brazilian Board of Orthodontics (CDBBO), will be president of the next WFO congress and is an "ambassador" of Brazilian Orthodontics in lectures all over the world. We mention her to represent the necessary recognition to pioneer women in Dentistry and Orthodontics in Brazil. So many others could be cited, since they open the doors to future generations, facing discrimination, restrictions and prejudices, and they have run an arduous way that served and serves as an example and inspiration for all.

Table 7: WFO[25] and ABOR[26] Congress Presidents (pink color for women; blue color for men).

Congress - year - location	Man	Woman
WFO - 2010 - Australia	1	
WFO - 2015 - London	1	
WFO - 2020 - Japan	1	
WFO - 2025 - Brazil		1
ABOR - 2011 - Belo Horizonte	1	
ABOR - 2013 - Natal	1	
ABOR - 2015 - Florianópolis	1	
ABOR - 2017 - Belém	1	
ABOR - 2019 - Rio de Janeiro	1	
ABOR - 2022 - Fortaleza		1

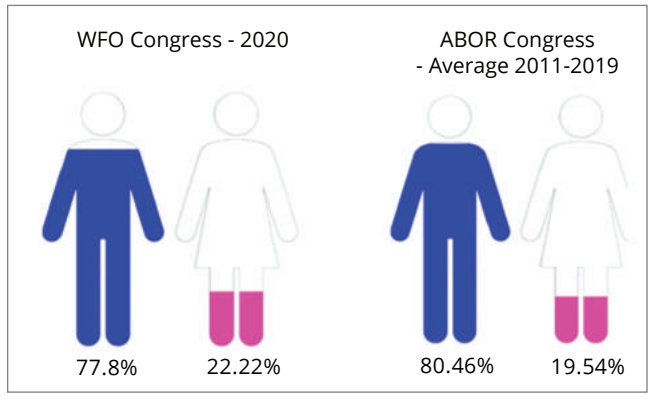


Analyzing the scientific program of ABOR Congresses from 2011 to 2019, with data summarized in Table 8, there was predominance of male over female speakers (average 80.46% of men and 19.54% of women). This same pattern can be observed internationally, analyzing the WFO and its Congresses, held at every 5 years, with predominance of men as presidents and majority as speakers in the scientific programs (Tables 7 and 8). The last WFO congress organized in Japan (2020), held online due to the Coronavirus Pandemic, presented a program with a total of 99 speakers, being 77 men and 22 women (77.78% and 22.22%, respectively) (Table 8).

Why are women majority in the profession and a minority in their exposure? Does acting as a leader make men keep their peers in prominent positions, feeding a structural pattern that reinforces the women's historical "invisibility"? Though unintentional, it could be a pattern of behavior, both for men and women, to consider this normal, as an outcome of the repetition of the current social structure. The way to achieve a more egalitarian society, with the same opportunities for men and women, begins with the manner through which the parents socialize and raise their children, boys and girls, without stereotypes or dream limitations and dissociating opportunities strictly linked to gender.

Table 8: Speakers at the WFO[25] and ABOR[26] Orthodontics congresses (pink color for women; blue color for men).

Congress - year	Total speakers	Speakers men	Speakers women
WFO - 2020	99	77 (77.78%)	22 (22.22%)
ABOR - 2011	79	67 (84.81%)	12 (15.18%)
ABOR - 2013	67	50 (74.62%)	17 (25.37%)
ABOR - 2015	85	71 (83.52%)	14 (16.47%)
ABOR - 2017	83	66 (79.51%)	17 (20.48%)
ABOR - 2019	139	111 (79.86%)	28 (20.14%)



FINAL CONSIDERATIONS

The goal of the authors in this paper was to review the history of women in Science to try to understand the possible causes of gender inequalities in the professional field. One of the questions raised was: if in Brazil, today, there is a significant number of dentists and if women are majority in Dentistry and Orthodontics, why would they not also be majority in the leadership of the profession? What would still prevent women from participating in decision-making centers, at the higher spheres? Are there biological differences between men and women? Or are there specific female limitations and difficulties in understanding and practicing Science? Are these factors due to cultural repression suffered throughout history?

Proportionally to the obstacles observed, the number of women in Science at all times is relatively large, and it would be totally erroneous to think that scientific and technological progress occurred without them.[2]

In the particular case of Dentistry and Orthodontics in Brazil, women's access to the Academy and to the job market occurred significantly after men, besides being guided by socio-structural issues, many of which are still present today.

There has been great progress and today women are present in all fields of Science, although there is no parity between genders. Since biologically they lead the pregnancy, and socially they are considered responsible for the process of child education and raising, women tend to be marginalized from the productive process, and consequently from strategic occupations. The social structure still considers compulsory motherhood and exclusive dedication as necessary for the scientific career, generating exclusion.[2] Historical causes and social factors still preclude from perceiving their importance and potential in organizations,[6] hindering or impeding their progression. There does not seem to be an explicit prejudice, but many men continue to act to guarantee the male hegemony in the highest positions[3], which is often reinforced by the behavior of women themselves in the way they raise their children or when they do not value the achievements and professional advancement of other women.

Conversely, men should not feel less capable when under the command of a woman. These issues must be faced with professionalism, and leadership must be exercised by meritocracy, regardless of gender. However, when the lowest wages are observed,[2,6] the reduced number of women in leadership positions[2] and the dedication necessary to reach a certain job, discrimination against women is visible, both in Brazil and abroad. The difficulty of women rising to high positions in organizations is so great that countries like Norway and Sweden have imposed a law on companies that obliges them to reserve a 40% quota for women in fiscal councils.[6] Initiatives as ongoing educational campaigns in Brazil, which encourage girls to become scientists, as well as programs to discuss unconscious prejudices are necessary.[22]

The indicators presented in this paper should serve as an alert for reflection, since any exclusion can be a form of violence, causing frustration and suffering.[2] We cannot remain insensitive to the inequalities of our time, not only in the field of Science, but also in how our society is structured. There are many challenges to overcome the “invisibility” of women and this requires awareness of all, especially of women, regarding the change in posture and social structure often favored by themselves, so that the next generations may live in a situation with greater equality of opportunities.

CONCLUSION

Knowing the history is important in raising the awareness of the persistent socio-structural issue that hides and masks female participation in Science. This reflection and review, based on data collected on the performance of women in Orthodontics in Brazil, can assist in defining the directions that can be followed, modifying the system consciously so that new generations may live in harmony and in a more equal manner. Women are already in a numerical majority in Dentistry and Orthodontics, but more important than that is to act more consistently. The necessary changes in the structure are not only of women and for women, but must involve the entire society, so that rights and duties are distributed equally between genders, while respecting the peculiarities inherent to each person.

AUTHORS' CONTRIBUTION

Cátia Cardoso Abdo Quintão (CCAQ)

Luísa S. da Costa Barreto (LSCB)

Luciane Macedo de Menezes (LMM)

Conception or design of the study:

CCAQ, LMM.

Data acquisition, analysis or interpretation:

CCAQ, LSCB, LMM.

Writing the article:

CCAQ, LSCB, LMM.

Critical revision of the article:

CCAQ, LSCB, LMM.

Final approval of the article:

CCAQ, LSCB, LMM.

Overall responsibility:

CCAQ, LMM.

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

REFERENCES

1. Matos VCS. Um estudo histórico das relações de gênero e classe. Rio de Janeiro: Saber Acadêmico. 2009 Jun [Access Feb 14, 2021];(7):57-73. Available from: http://uniesp.edu.br/sites/_biblioteca/revistas/20180403123533.pdf.

2. Kovaleski NVJ, Tortato CSB, De Carvalho MG. As relações de gênero na história das ciências: a participação feminina no progresso científico e tecnológico (Gender relations in the history of science: The women´ s participation in the scientific and technological progress. Paraná: Emancipação. 2013 [Access Feb 14, 2021];13(3):9-26. ISSN-e1982-7814. Available from: https://dialnet.unirioja.es/servlet/articulo?codigo=5456430.

3. Costa MC. Ainda somos poucas: exclusão e invisibilidade na ciência. Cad Pagu. 2006; Campinas, (27):455-59.

4. Neri C. Feminismo na Idade Média: conhecendo a cidade das damas. G&D [Internet]. 2013 Sep [Access Feb 14, 2021];25;2(1). Available from: https://periodicos.ufpb.br/ojs2/index.php/ged/article/view/16950.

5. Tosi L. Mulher e ciência: a revolução científica, a caça às bruxas e a ciência moderna. Cad Pagu. 1998; Campinas [Access Feb 14, 2021];(10):369-97. Available from: https://periodicos.sbu.unicamp.br/ojs/index.php/cadpagu/article/view/4786705.

6. Tezza LSL, Perussello BA, Soboll LA. Discriminação da mulher no mercado de trabalho. Análise histórica da representação social da mulher no contexto capitalista. Sessões temáticas: gênero, sexualidade, etnia e geração. 2007. In: Anais do XIV Encontro Nacional da Associação Brasileira de Psicologia Social- ABRAPSO-Trabalhos Completos. ISSN: 1981-4321. [Access Feb 14, 2021]. Available from: http://www.abrapso.org.br/siteprincipal/anexos/AnaisXIVENA/conteudo/pdf/trab_completo_191.pdf.

7. Leta J. As mulheres na ciência brasileira: crescimento, contrastes e um perfil de sucesso. São Paulo, Estud. av. 2003 Dec;17(49):271-84.

8. Araujo MF. Diferença e igualdade nas relações de gênero: revisitando o debate. Psicol clin. 2005; Rio de Janeiro, 17(2):41-52.

9. Messias MCN, Jacó-Vilela AM. Relações de gênero e poder na Belle Époque: entre discursos e práticas. Psicol Pesqui. 2018; Juiz de Fora, 12(3):1-10.

10. Ostos NSC. A questão feminina: importância estratégica das mulheres para a regulação da população brasileira (1930-1945). Cad Pagu. 2012 Dec; Campinas, 39: 313-343.

11. Pinsky CB, Pedro JM. Nova história das mulheres no Brasil (Portuguese Edition). São Paulo: Editora Contexto. 2013.

12. Rosenberg F, Madsen N. Educação formal, Mulheres e Gênero no Brasil contemporâneo. In: Barsted LL, Pitanguy J, editors. O progresso das Mulheres no Brasil 2003-2010. Rio de Janeiro: CEPIA, Brasília: ONU Mulheres; 2011. 390-434 p.

13. Mott ML, Alves OSF, Muniz MA, Martino LVS, Santos APF, Maestrini K. 'Moças e senhoras dentistas': formação, titulação e mercado de trabalho nas primeiras décadas da República. História, Ciências, Saúde-Manguinhos. 2008 Jun; 15(Suppl.):97-116.

14. Rothier EK. Sociedade Brasileira de Ortodontia: sua história e trajetória científica. Rio de Janeiro: SBO. 2005.

15. Morita MC, Uriarte Neto M, Fontanella VRC, Haddad AE. The unplanned and unequal expansion of Dentistry courses in Brazil from 1856 to 2020. Brazilian Oral Research. 2020;35:1-10.

16. Conselho Federal de Odontologia [Internet]: CFO; 2020 [cited 2020 Dec 24]. Available from: https://website.cfo.org.br/cfo-discute-pos-em-ortodontia-na-camara/.

17. American Association of Orthodontists [Internet]: AAO; 2020 [cited 2020 Dec 24]. Available from: https://www.aaoinfo.org/education/accredited-orthodontic-programs.

18. Vilella OV. O desenvolvimento da Ortodontia no Brasil e no mundo. Rev. Dent Press Ortod. Ortop Facial. 2007 Dec;12(6):131-156.

19. Conselho Federal de Odontologia [Internet]: CFO; 2020 [cited 2020 Dec 30]. Available from: https://website.cfo.org.br/sistema-de-especializacao/?doing_wp_cron=1610746846.1039729118347167968750.

20. Conselho Federal de Odontologia [Internet]: CFO; 2020 [cited 2020 Dec 29]. Available from: https://website.cfo.org.br/dados-estatisticos-de-profissionais-e-entidades-ativas-por-especialidade/.

21. Anais do XIX Encontro da Associação dos Ex-Alunos Pós-graduados em Ortodontia da UFRJ [Internet]: Maceió, AL, 119f; 2019 [cited 2020 Dec 24]. Available from: https://adepoufrj.com.br/dfd.php?i=2790B855-481F-4F63-8BAF-BC3EE45DA147.

22. Negri F. Women in Science: Still Invisible? In: Picanço L, Prusa A, editors. A Snapshot of The Status of Women in Brazil: 2019. Washington: Brazil Institute, Wilson Center; 2019. p. 18-19.

23. Conselho Nacional de Pesquisa e Desenvolvimento - Diretórios dos Grupos de Pesquisa no Brasil - Plataforma Lattes (Busca com palavra-chave "Ortodontia") [Internet]: CNPq; 2020 [cited 2020 Nov 03]. Available from: http://lattes.cnpq.br/web/dgp.

24. Dental Press Journal of Orthodontics [Internet]: DPJO; 2020 [cited 2020 Dec 24]. Available from: https://br.dpjo.net.

25. World Federation of Orthodontists [Internet]: WFO; 2020 [cited 2020 Dec 29]. Available from: http://www.wfo2020yokohama.org/index.html.

26. Associação Brasileira de Ortodontia e Ortopedia Facial [Internet]: ABOR Nacional; 2020 [cited 2020 Dec 29]. Available from: https://abor.org.br

27. Holder D & Artese F. Associação Brasileira de Ortodontia e Ortopedia Facial. Gazetas ABOR: 25 anos de união e defesa da Ortodontia Brasileira [Internet]. Maringá: Dental Press; 2018 [cited 2019 Jul-Dec 29]:336. Available from: https://abor.org.br/gazetas Subscription required.

28. Board Brasileiro de Ortodontia e Ortopedia Facial [Internet]: BBO; 2020 [cited 2020 Dec 29]. Available from: https://bbo.org.br/diplomados.