

ALESSANDRA GENEROSI BARBEDO

MAXILLARY DISJUNCTION: THE EFFECTIVENESS OF MARPE METHOD IN
THE PALATINE SUTURE – A NARRATIVE REVIEW

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Trabalho apresentado à Universidade Fernando
Pessoa como parte dos requisitos para obtenção do grau
de Mestre em Medicina Dentária.

Alessandra Generosi Barbedo

RESUMO

A disjunção da maxila com finalidade de corrigir a atresia do arco dentário superior, consiste na abertura da sutura intermaxilar e consequente aumento transversal da base óssea. O objetivo deste trabalho foi avaliar através de uma revisão narrativa a ação do método de disjunção “Microimplant Assisted rapid Maxillary Expansion” (MARPE) na sutura palatina, bem como avaliar outros parâmetros como inclinação dentária, efeitos periodontais e ósseos além da resultante da distribuição de stress causado pela disjunção. A fim de identificar os estudos relevantes, foi realizada uma busca através do motor de pesquisa PubMed, incluindo estudos publicados entre os anos de 2010 a 2021. A seleção dos estudos respeitou os critérios de inclusão e exclusão pré - definidos. Após a avaliação dos artigos selecionados, os resultados das pesquisas permitiram concluir que o método MARPE é eficaz na abertura da sutura palatina, porém apresenta efeitos dentários secundários.

Palavras-chave: Ancoragem Ortodôntica, Expansão Maxilar, Ortopedia, Maloclusão.

ABSTRACT

The maxillary disjunction with the purpose of correcting the atresia of the superior dental arch, consists in the opening of the intermaxillary suture and consequent transversal increase of the bone base. The objective of this work was to evaluate, through a narrative review, the action of the disjunction method "Microimplant Assisted rapid Maxillary Expansion" (MARPE) in the palatal suture, as well as to evaluate other parameters such as dental inclination, periodontal and bone effects in addition to the resultant of the distribution of stress caused by the disjunction. In order to identify the relevant studies, a search was performed using the PubMed search engine, including studies published between the years 2010 to 2021. The selection of studies respected the pre-defined inclusion and exclusion criteria. After evaluating the selected articles, the results of the research allowed to conclude that the MARPE method is effective in opening the palatal suture, but it has secondary dental effects.

Keywords: Orthodontic Anchorage, Maxillary Expansion, Orthopedics, Malocclusion.

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LIST OF ABBREVIATIONS AND ACRONYMS

BBME - Bone-Borne Maxillary Expander

CBCT - Cone-beam computed tomography

FEM – Finite Element Method Analysis

MARPE - Mini-screw Assisted Rapid Palatal Expansion

MEDLINE - Medical Literature Analysis and Retrieval System Online

MSE – Mini-Screw Expansion

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

RME – Rapid Maxillary Expansion

RPE – Rapid Palatal Expansion

SARPE - Surgically Assisted Rapid Palatal Expansion

TBME - Tooth-Borne Maxillary Expander

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Figure I. Fluxogram of research and literature review process for the selection of studies to be included in the sample of the systematic review.

I. INTRODUCTION

The population awareness of oral health, the aesthetic requirements of society and the current easy access to orthodontic treatment encourage the patient or legal guardian to seek specialized treatment. Among the common dental malocclusions presented in Dentistry, transverse maxilla deficiency is one of the most common and is one of the most damaging skeletal problems of the craniofacial region in both young people and adults (McNamara, 2000).

Transverse maxillary deficiency can contribute to uni or bilateral crossbite, anterior dental crowding, as well as a marked oral corridor enlargement during the smile and a narrowing of the nasopharyngeal cavity (Ozçirpi *et al.*, 2014; Park *et al.*, 2015). When a skeletal constricted maxillary arch is diagnosed, orthopedic skeletal expansion involving separation of the midpalatal suture is the treatment of choice (Lagravere *et al.*, 2005).

Rapid Maxillary Expansion (RME) is routinely employed in cases of real maxillary deficiency to correct transverse skeletal and dental discrepancies or to increase the perimeter of the upper arch (McNamara, 2000). The most effective treatment aims to increase the maxillary transverse measurement, disrupting the medial palatal suture, through the disjunction of the maxilla. In addition it is one of the safest and most reliable orthodontic procedure (Liu and Zou, 2015).

It was first described by Angel, in 1860, and popularized a hundred years later with research by Haas, who in 1961 analysed plaster models and cephalometric radiographs performed before, during and at the end of the expansion treatment, in an experimental study. He analyzed the quantity of opening of the median palatine suture, the increase in the width of the upper arch followed by the widening of the lower arch and increased intranasal capacity (Haas, 1961).

Several devices have been developed to perform maxillary expansion, from removable acrylic devices with a central screw to bonded or banded expanders (Sandikçlou e Hazar, 1997; Berger *et al.*, 1998; Akkaya, S. *et al.*, 1999). Two types of palatal expanders are widely recognized in the literature, a teeth-muco-supported (Haas type) and a teeth-supported (Hyrax type), and there is still no consensus to support what type of device generates the greatest orthopedic effects and less discomfort to the patients (Siqueira, 2000; Oliveira *et al.*, 2004).

However, the dental anchorage can cause some side effects, such as periodontal problems, inclination and extrusion of the supporting teeth, which can also open the bite in the anterior sector and provoke a posterior rotation of the mandible; in addition there is the risk of relapse of the treatment. Serious pain, mucosal ulceration or necrosis, and accentuated buccal tipping have been also observed after RME failure (Angelieri *et al.*, 2016).

Regarding periodontics possible alterations, the supporting teeth may show root resorption, dehiscence, gingival retraction and bone fenestration (Garib *et al.*, 2004). Previous studies also described a reduction of the cortical bone of posterior teeth after using rapid maxillary expander. The reduction of cortical bone was even more pronounced on the teeth that served as direct anchorage to the expander, which was attributed to the tipping movement of the teeth (Rungcharassaeng *et al.*, 2007; Garrett *et al.* 2008). Furthermore, this treatment modality comes with some limitations, such as age, dentoalveolar tipping, root resorption, and bone dehiscence, as well as, the lack of long-term stability (Lin *et al.*, 2015).

Surgically Assisted Rapid Palatal Expansion (SARPE) is a treatment modality that helps overcome increased resistance from the bony palate and zygomatic buttress in adults (Shetty *et al.*, 1994; Asscherickx *et al.*, 2016). However, SARPE has several limitations, including high cost, a complex treatment process, and surgical morbidity (Williams *et al.*, 2012). Another factor is that most patients are reluctant to undergo this surgical procedure. Therefore, several efforts have been made to minimize the surgical indications and minimize the limitations of RPE.

To ensure expansion of the basal bone without surgical intervention and maintain the separated bone in consolidation, Lee *et al.* (2010) introduced a miniscrew-assisted palatal expansion (MARPE) appliance and reported successful expansion of the maxilla through opening of the midpalatal suture.

The aim of the present narrative review is to evaluate and analyse the MARPE (mini-screw assisted palatal expansion) method for maxillary disjunction addressing skeletal and dento-alveolar changes, as well as seeking to compare with dental anchorage devices.

As an academic objective, we considered it to analyze the information available and contextualizing the findings of the relevant articles and approach the determining factors and parameters that can help professionals to decide which type of anchorage use to perform the palatal disjunction, as well as to show some findings about possible collateral damages. Furthermore, palatal expansion is one of the most common problems faced by orthodontists and it is very important to correlate findings which could be helpful in daily routine.

1.1. Materials and Methods

The key words were chosen and a computerized search was conducted on the search engine PubMed, selecting articles published from 2010 to 2021. A table was built to record the number of articles found (table I). The research was conducted as follows: keywords individually, keywords grouped two by two and three by three using Boolean markers (AND). The following inclusion criteria were chosen to initially select the appropriate articles from the published titles and then the abstract reading: articles published in the last 10 years, articles with measurements and evaluation from Cone Beam Computed Tomography (CBCT) data and samples aged between 8 to 16 years old. In addition to the palatine suture expansion evaluation, some specific parameters were chosen to compose this research such as dental inclination, periodontal and bone alteration, and stress distribution during expansion. Eligibility of potential studies was determined by reading the title and abstracts of each article identified by each search engine.

Reference lists of the selected articles were hand-searched for additional relevant publications that may have been missed in the database search. This narrative review was carried out in accordance with the terms and regulations provided. The articles relevant to the review were chosen by the author.

Keywords	2010-2021
Orthodontic Anchorage	2.298
Maxillary Expansion	2.071
Orthopedics	271.044
Malocclusion	10.521
Orthodontic Anchorage AND Maxillary Expansion	261
Orthodontic Anchorage AND Orthopedics	256
Orthodontic Anchorage AND Malocclusion	971
Maxillary Expansion AND Orthopedics	280
Maxillary Expansion AND Malocclusion	775
Orthopedics AND Malocclusion	881
Orthodontic Anchorage AND Maxillary Expansion AND Orthopedics	50
Maxillary Expansion AND Orthopedics AND Malocclusion	144
Orthodontic Anchorage AND Maxillary Expansion AND Malocclusion	169
Orthopedics AND Malocclusion AND Orthodontic Anchorage	130
Keywords AND Systematic Review	1

Table I. Articles found according to the research methodology.

As a result of the bibliographic search, 35 articles were selected for a complete reading of the text. After examining the articles, 27 articles were excluded because they met the exclusion criteria for this review, which presented other simultaneous treatment that could affect RME effect during the evaluation period, clinical trials in adults and articles presenting evaluation of parameters that were not relevant for the search. Repeated articles and non-accessible articles were also. A total of 8 articles, published between 2010 and 2021, met the inclusion criteria and were selected for analysis and data extraction (Fluxogram I). Furthermore, 31 articles were also obtained by cross-reference, 13 articles within and 18 articles outside the research time range, which were used because they add value to the work.

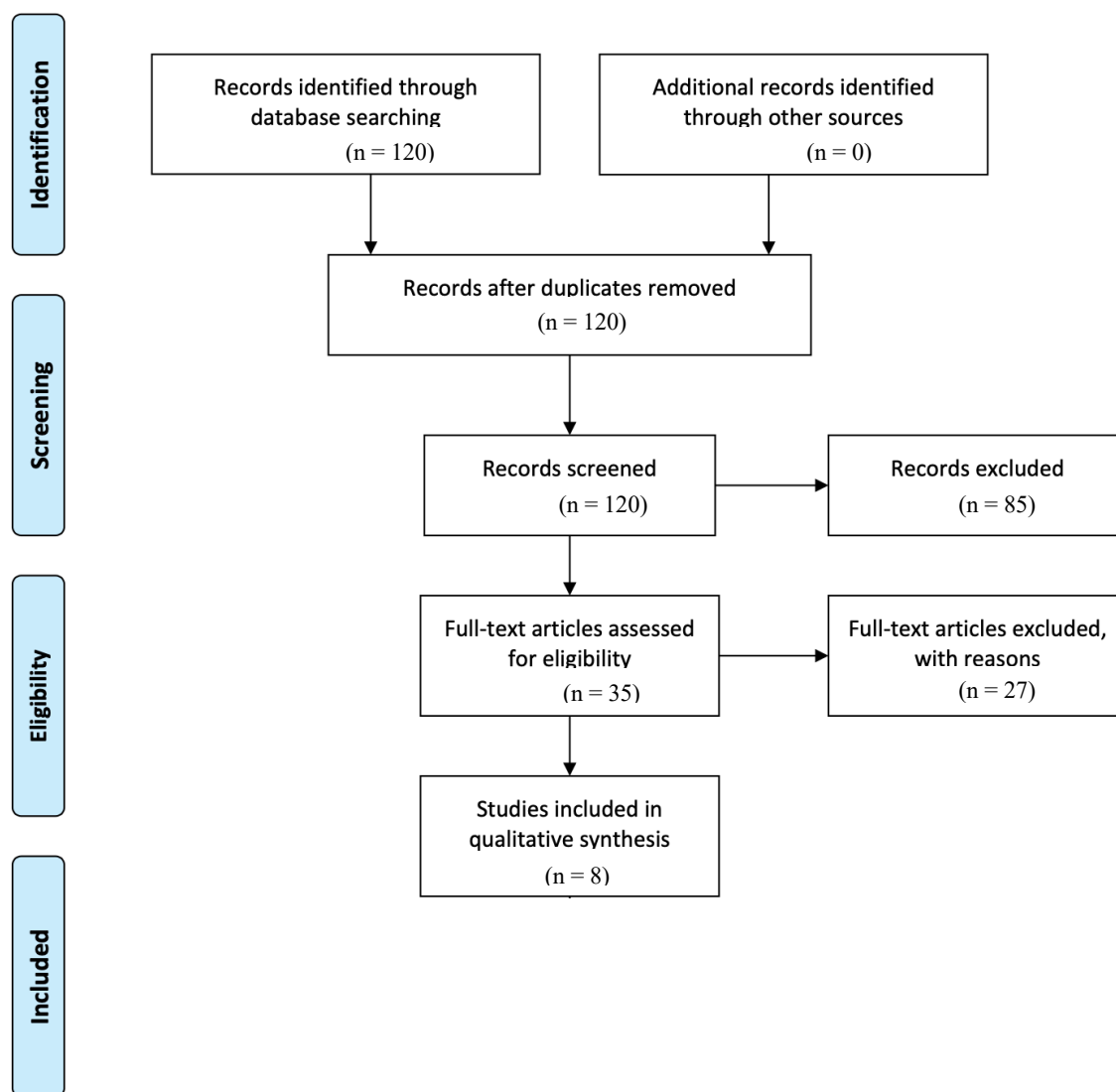


Figure I. Fluxogram representative of the research and literature review process for the selection of studies to be included in the sample of the narrative review. Where “n” represents the number of articles found.

II. DEVELOPMENT

2.1 Maxillary Disjunction

The prevalence of maxillary transverse deficiency is 8% to 23% in the deciduous or mixed dentitions and a little less than 10% in adult orthodontic patients (Silva Filho *et al.*, 2007). While the cause of maxillary constriction is multifactorial, one way to alleviate this skeletal deficiency is through rapid maxillary expansion (RME) (MacGinnis *et al.*, 2014).

Rapid maxillary expansion is the treatment of choice in adolescents and young adults to separate the midpalatal suture and induce significant maxillary changes and to obtain clinically stable results in the underlying structures. (Mosleh *et al.*, 2015).

RME consists in separating the two maxillary bones at the midpalatine suture during expansion. The force produced by the appliance counteracts the existing anatomical resistance from the dentoalveolar, midpalatal suture, zygomaxillary buttress, and circummaxillary sutures (Haas, 1961; Garib *et al.*, 2004; Garrett *et al.*, 2008).

Previous studies from Lee *et al.* (1997) have identified the center of resistance of the maxilla in both the sagittal and frontal views. From a frontal view, the centers are referred to an intersection of two axis: the first through the crista galli and the second through the most inferior points of the zygomaticomaxillary sutures bilaterally. The center of resistance is located at the perpendicular intersection of these two axes. From a lateral view, the center of resistance is located along a line passing through the distal contact of the maxillary first molar to the functional plane and then taking half of the distance from the functional plane to the inferior border of the orbit (MacGinnis *et al.*, 2014).

Mini-Screw Expansion (MSE) might be considered beneficial for maxillary expansion on non-growing patients with possible more skeletal effects. (Hartono *et al.*, 2018).

The bone-borne RME group in the Celenk-Koca *et al.* (2018) study produced more skeletal separation, following suit to previously introduced miniscrew-supported RME appliances facilitating the direct transfer of expansion forces to the palate. This is an ideal outcome because a true increase in transverse width of the basal bone in cases with maxillary transverse deficiency is essential to the ideal finishing of the case. Heavy stainless-steel wires used in the final stages of comprehensive orthodontic treatment would introduce negative torque to the posterior teeth, restoring the ideal buccolingual inclinations of the teeth and possibly decreasing the amount of expansion previously gained by tipping of the posterior teeth buccally.

The classification of midpalatal sutural fusion using CBCT allows the diagnosis of the overall antero-posterior characteristics of the midpalatal suture, without overlapping other anatomic structures (Angelier *et al.*, 2013). This method might provide reliable parameters for the clinical decision between conventional RME or MSE for adolescent and young adult patients.

2.2 Mini-screw Assisted Palatal Expansion – MARPE

The use of miniscrews in palatal area was firstly introduced because palatal was covered with keratinized gingiva and gave good flexibility. The miniscrew-assisted rapid palatal expansion (MARPE) was proposed by Lee *et al.* in 2010, aiming to solve the undesirable dentoalveolar effects and optimize the potential of skeletal expansion in individuals in advanced stages of skeletal maturation. An effective separation of the midpalatal suture was observed in an adult patient with mild buccal inclination of maxillary molars.

Weissheimer *et al.* (2011) reported that the use of Rapid Maxillary Expansion (Haas-type and Hyrax-type) alone gave smaller effects at the skeletal level and Lagravere *et al.* (2005) referred that the effects of rapid maxillary expander with bone anchorage produced less dental tipping than rapid maxillary expander alone.

Those studies (Weissheimer *et al.*, 2011; Lagravere *et al.*, 2005) reported that miniscrew-assisted rapid maxillary expander were effective in preventing the negative side effects that were commonly seen with rapid maxillary expander alone. Therefore, many clinicians opted for miniscrews as a non-invasive expansion alternative method. With the innovation of miniscrews, it is now possible to reinforce the anchorage system of rapid maxillary expander without the support of tooth structure because miniscrews serve as the orthodontic absolute anchorage.

Bone anchored rapid maxillary expander were reported to transmit a direct expansion force to the palatal bone, which contribute in a more skeletal opening of the suture, instead of bending of the maxillary alveolar bone as the force vector located near the bone (Hartono *et al.*, 2018).

Questions have been raised about non-surgical maxillary expansion in adults, and the consensus is that once patients are out of adolescence, conventional expansion is no longer feasible (Lee *et al.*, 2014). Interestingly, MacGinnis *et al.* (2014) demonstrated that with the fused suture model, maxillary expansion with MARPE may be possible if the expansion

force can split the suture. Applying a significantly higher level of force may be possible without adversely affecting the surrounding structures.

The fixation of mini-screws must be bicortical, including the cortical of the palate and nasal fossa, this being essential to overcome the resistance of the maxillary bones separation (Nojima *et al.*, 2018).

From a clinical perspective, placement of the jackscrew should be as close to the center of resistance as possible to effect a more translatory movement of the maxillary halves. With a conventional hyrax, it is impossible to direct the force from the jackscrew through the center of resistance to produce pure bodily movement. It is believed that with a more rigid expansion appliance, the center of rotation will move superiorly and posteriorly (Braun *et al.*, 2000; MacGinnis *et al.*, 2014).

Since the greatest resistance to opening is found between the maxilla sutures and the pterygoid pillars, the forces should be applied more posteriorly, promoting a parallel separation of the median palatal suture. By applying forces directly to the resistance center of the maxilla through the mini-implants, a force system is promoted that favors a homogeneous and parallel opening of the suture (Lee *et al.*, 2014; MacGinnis *et al.*, 2014).

Tausche *et al.* (2008) reported that MARPE is a viable expansion technique, allowing for the protection of teeth and preventing buccal tipping of the posterior dentoalveolar segment by 10°. Additionally, Nienkemper *et al.* (2013) reported that the mentioned side effects of RME appliances can be minimized using a hybrid hyrax device that is connected to two orthodontic micro-implants in the anterior palate and is also attached to the first molars.

2.3 Palatine Suture

The midpalatal suture is wrinkled and arranged in an overlapping as well as sinuous pattern, with bone margins with thick connective tissue interposed between them in three to five layers. It should be highlighted that the midpalatal suture: 1) Does not represent the fusion of maxillary palatal processes only, but also the fusion of alveolar palatal processes of the jaws and horizontal osseous laminae of palatal bones. Changing it implies affecting neighbouring areas. 2) It has three segments that should be considered by all clinical analyses, the anterior segment - before the incisive foramen, or intermaxillary segment; the middle segment - from the incisive foramen to the suture transversal to the palatal bone and the posterior segment - after the suture transversal to the palatal bone. Morphological and clinical-therapeutic approaches often aim at the midpalatal suture, but do not include its

anterior segment. Likewise, they occasionally aim at its posterior segment (Suzuki *et al.*, 2016).

Understanding individual variability in the fusion of the midpalatal suture is essential in identifying prospectively which late adolescent or young adult patient can have RME as a less-invasive alternative to surgically assisted expansion. The midpalatal suture has been described as an end-to-end type of suture with characteristic changes in its morphology during growth (Angelieri *et al.*, 2013). In the infantile period, Melsen (1975) reported that the midpalatal suture is broad and Y-shaped in its frontal sections.

In the treatment of transverse maxillary deficiencies, especially among adolescents, orthopedic expansion of the maxilla along the median palatal suture holds a prominent place (Krusi *et al.*, 2019). Both intermittent and continuous forces are routinely applied to expand sutures in patients with maxillary deficiencies.

Palatal expanders, which are used by the vast majority of orthodontists (Keim *et al.*, 2002), are intermittently activated, but apply a continuous residual force across the suture during active treatment. The success rate of maxillary disjunction or expansion is directly related to how much opening of the palatal suture is achieved.

2.4 Dental Inclination

Several studies have reported the amount of tipping presented during this treatment, with ranges from 0° to 24° . (Lagravere *et al.*, 2013).

Conventional RME provokes an orthodontic effect of buccal tipping and movement of the posterior teeth (MacGinnis *et al.*, 2014).

With the innovation of implants, a paradigm shift has occurred to the anchorage perspective, and it has been possible to reinforce anchorage during rapid maxillary expansion without dental support. Miniscrews have been used as a means of absolute orthodontic anchorage. Bone-anchored palatal expanders were claimed to transmit the expansion forces directly to the palatal bone, contributing to more skeletal movement rather than to bending of the maxillary alveolar shelves (Mosleh *et al.*, 2015). This may allow for more physiologic sutural expansion, reduce negative dental effects, and contribute toward more efficient mechanics.

In addition, the advantages of greater orthopedic efficiency would also be extended to a critical field of orthodontics and maxillary expansion: longitudinal stability. Although the orthopedic effect may also show some degree of recurrence, previous studies have shown that

the dental effect represents the most unstable alteration after expansion (Suzuki *et al.*, 2016). Suzuki and collaborators (2016) also refers that based on these results, it is expected that the greater the skeletal effect and the lower the tooth movement, for a given amount of screw activation, the better the prognosis in terms of stability.

2.5 Periodontal and Bone Effects

MARPE technique comprises the insertion of four miniscrews adjacent to the midpalatal suture, being two mesial and two distal to the expanding screw. Among the anatomical characteristics at this area, the mean thickness of bone present in the regions mesial and distal to the expanding screw varies (Lee *et al.*, 2010).

Nojima *et al.* (2018) refer that a correct selection of mini- screw length by analysis of bone tissue thickness and height of midpalatal suture, assessed by CBCT examination, is relevant for the success of MARPE.

Tooth-borne expanders, which concentrate the force at the dentoalveolar area, might be more iatrogenic from a periodontal standpoint and might cause more root resorption than tooth-tissue-borne expanders, which distribute the force between the anchorage teeth and the palatal surface. The impact on the buccal bone plate from both types of expander could be extremely important (Garib *et al.*, 2004).

According to Melsen (1999), buccolingual tooth movement can occur concurrently with or through the alveolar bone. The first situation occurs only with direct or frontal bone resorption. In this case, there would be resorption of the bone surface at the periodontal ligament pressure area, with compensatory bone apposition at the external surface of the alveolar process. However, when the force magnitude induces indirect bone resorption, the clasts resorb the bone plate of the external surface in the direction of the periodontal ligament, therefore leading to tooth movement through the thin alveolar bone plate.

III.DISCUSSION

3.1 Palatine Suture

Krusi *et al.* (2019) findings shows that several skeletal maxillary relevant differences were identified. Their study, a systematic review with meta-analysis, included six randomized clinical trials comparing bone-borne or hybrid tooth-bone-borne RME to conventional tooth-borne RME, where one trial indicated that bone-borne RME was associated with greater

skeletal expansion at the incisal foramen, greater suture opening at the first premolar and greater suture opening at the first molar than tooth-borne RME. Furthermore, three different single trials provided evidence that bone-borne RME was associated with less intercanine width expansion, less inter-first-premolar width expansion than tooth-borne RME. From another perspective and considering their findings, despite limited evidence from randomized trials, literature tends to confirm that bone-borne or hybrid tooth-bone-borne RME might present advantages in terms of increased sutural opening compared to conventional tooth-borne RME.

A FME study from MacGinnis *et al.* (2014) where a three-dimensional mesh model of the cranium with associated maxillary sutures was developed using computed tomography images and mimics modeling software refers that by placing expansion forces closer to the maxilla's center of resistance, less tipping occurs with a more lateral translation of the complex. Additionally, this study compared transverse expansion stresses in rapid palatal expansion (RPE) and MARPE. Expansion forces were distributed to differing points on the maxilla and evaluated with ANSYS simulation software, and suggested that MARPE can be beneficial in patients with sutures that are fused. Moreover, they stated that applying a significantly higher level of force may be possible without adversely affecting the surrounding structure. Stress distribution from MARPE showed less propagation to the buttresses and adjacent locations in the maxillary complex. This study raises two important advantages that may be considered; not only the benefits of MARPE in sutures that are already fused, but also the beneficial in young dolichofacial patients by helping to prevent bone bending and dental tipping.

Mosleh *et al.* (2015) evaluated and compared the transverse dentoskeletal changes concurrent with 4-point bone-borne (BBME) and tooth-borne rapid maxillary expanders (TBME) in growing female patients with 12 years old. A superimposition from before and after Cone-Beam Computed Tomography (CBCT) images was made and their results showed that in skeletal maxillary and circummaxillary measurements, the BBME group had statistically significant increases in facial and maxillary widths. On the other hand, TBME group had a great increase in nasal width. From a clinical perspective, after the results referred, we could consider the idea of applying a BBME especially in cases that we don't have posterior teeth, while TBME could be beneficial in situations that require more dental expansion.

When comparing skeletal changes with the utilization of conventional (tooth-borne)

or miniscrew-supported (bone-borne) maxillary expansion appliances in adolescents, Celenk-Koca *et al.* (2018) results showed the ratios of sutural expansion in the maxillary first premolars area, where the total increase in maxillary width were 28% and 70% in the tooth-borne and bone-borne expander groups, respectively. Similarly, apparently 26% and 68% of the total expansion was of skeletal nature in the tooth-borne and bone-borne expander groups in the area of the maxillary first molars. Therefore, they concluded that the bone-borne expansion group had almost three times greater expansion in the midpalatal suture than did the tooth-borne group. In my perception, after analysing this article, we can think about using bone anchorage when the amount of suture opening is something significant without excluding the possibility of side effects.

Krusi *et al.* (2019) alerts that some caution is warranted in the interpretation of findings, since this might be attributed to the limited number of trials with small sample sizes and heterogeneous results or to the fact that studies measured this outcome separately for right and left teeth.

An indirect way to measure maxillary expansion in conjunction with tooth tipping might be to look at the buccal bone thickness at the first premolars and the first molars. Another outcome often measured in trials comparing bone-borne or hybrid RME to conventional RME is the dental arch width—usually at the first premolars or the first molars area. Existing data indicated no significant difference in this dental arch width for either skeletally anchored RME compared to conventional RME. Overall, there exist some indications of potential benefits from partially or completely skeletally anchored RME, but only a few trials with very limited sample sizes and some risk of bias exist, which hampers our confidence in drawing clinical recommendations. (Krusi *et al.*, 2019).

3.2 Dental Inclination

In a systematic review with meta-analysis from Krusi *et al.* (2019) comparing tooth-borne and bone-borne expansion only some dental positional/inclination significant differences were reported from a single trial. As such, bone-borne RME was associated with less dental expansion at the canine area, less buccal tipping at the first premolar area, and less buccal tipping at the first molar compared to tooth-borne RME. Additionally, a meta-analysis (Canan *et al.*, 2017) of two trials indicated that bone-borne RME was associated with less buccal tipping of the first premolar and first molar.

In the study of Mosleh *et al.* (2015) regarding dento-angular measurements, no

statistically significant decrease was perceived for the external buccopalatal inclination angle of the maxillary first premolars and first permanent molars in the Bone-Borne Maxillary Expander (BBME) group. In the Tooth-Borne Maxillary Expander (TBME) group, a statistically significant decrease was detected only for the bucco-palatal inclination angle of the maxillary right and left first premolars. By comparison, TBME group showed a statistically significant higher decrease in the external inclination angle of the maxillary right and left first premolars than did the BBME group. No statistical significance was detected for the external bucco-palatal inclination angles of the maxillary right and left first permanent molars.

MacGinnis *et al.* (2014) says that MARPE is also beneficial in young dolichofacial patients by helping to prevent bone bending and dental tipping.

Domann *et al.* (2011) evaluated the immediate effects of RME with Hyrax appliances on the dentoalveolar complex using CBCT. Their results showed a significant tipping of the palatal roots of the maxillary right and left premolars as well as that for the maxillary left molar. When present, the thickness of the buccal plate decreased on all observed roots. Therefore, they concluded that the increase in root angulation suggests that the movement is more of tipping than translation. With their study and conclusions, we may be alert with dental effects and whatever is the device of choice, side effects exist and should be taken into consideration by the time of planning the treatment.

Celenk-Koca *et al.* (2018) concluded that the use of bone-borne expansion in the adolescent population increased the extent of skeletal changes in the range of 1.5 to 2.8 times that of tooth-borne expansion and did not result in any dental side effects.

Lagravere *et al.* (2013) did a meta-analysis on immediate changes presented after maxillary expansion and reported a 3.1° intermolar angle increase. According to their study, which performed a comparison between control group, tooth-borne and bone-borne groups, the first and second molars of both bone- and tooth- anchored treatment groups showed a difference in dental inclination than the control group. In fact, the second molar showed that the bone-borne group was even significantly different from the control group at baseline. For the second premolars, only the tooth-borne group was significantly different from control. The tooth-anchored group was also significantly different from the control group in the first premolar measurements.

3.3 Periodontal and Bone Effects

The study of Hartono and collaborators, that used expansion simulation (Hartono *et al.*, 2018) comparing Rapid Maxillary Expander (RME) and Mini-Screw Expander (MSE) showed a similar stress distribution on the palatal alveolar bone of the upper first molar. Von Mises stress distribution showed the highest stress on the mesial alveolar bone of the upper first molar in the RME group, while in the MSE group, the highest stress was found on the palatal alveolar bone of the upper first molar. MaxPS distribution showed the highest tension on the mesial alveolar bone of the upper first molar in the RME group, while in the MSE group, the highest tension was found on the apical part of the palatal alveolar bone of the upper first molar. MinPS distribution showed the highest compression on the mesial alveolar bone of the upper first molar in the RME group, while in the MSE group, the highest compression was found on the bifurcation of the palatal alveolar bone of the upper first molar.

Three studies from Krusi *et al.* (2019) article evidenced that a greater buccal bone thickness at the first premolar was shown in bone-borne RME.

In a study with CBCT images pre and post-expansion using Hyrax expander (tooth-borne), Domann *et al.* (2011) concluded that the thickness of the buccal plate decreases immediately after RME. Therefore, the level of inflammation should be closely monitored to avoid periodontal destruction.

Celenk-Koca *et al.* (2018) findings showed that bone-borne expansion resulted in uprighting of the maxillary posterior teeth with significant benefit to the buccal alveolar bone support.

Lagravere *et al.* (2013) referred in their article that the distances between alveolar bone and root apex (first and second molars and premolars, right and left sides) landmarks did not show any clear trends over the course of treatment. Although it varied by tooth localization, alveolar bone-to-root apex distances were very small, with many being less than 0.5 cm.

Garib *et al.* (2004) stated that some investigators have shown strong correlations between buccal tooth movement and bone dehiscences in animals. However, few researchers have reported on periodontal status after RME, especially in humans. This might be because conventional radiographs, which comprise most orthodontic records, show 2-dimensional and superimposed images and do not show the thickness and the level of the buccal and lingual bone plates.

The previous study justifies the need to define the periodontal consequences of RME, which is a routine treatment in clinical orthodontic practice, has led to the use of computed tomography (CT), a precise and useful tool in this kind of investigation. CT diagnostic imaging uses x-rays and allows reproduction of a real maxillary section in any plane, showing all anatomical structures in depth. Although radiation exposure must be minimized as possible and protection procedures must be implemented as preconized by most dental guidelines (ADA, 2021).

Vardimon *et al.* (1991) explains that the intense force delivered on the supporting teeth during activation of the screw leads to hyalinization of the periodontal ligament on the pressure side. Initially, tissue necrosis would be positive, since it would obstruct alveolar bone resorption and consequent orthodontic tooth movement. Unable to move, the teeth become ideal supporting units for maxillary orthopedic movement. Therefore, at the onset of expansion, the accumulated force is used to promote maxillary splitting. Probably afterwards, with the permanence of residual forces left because the orthopedic effect is smaller than the amount of expansion, the orthodontic effect occurs. The negative consequences of periodontal ligament hyalinization can then appear, represented by the supporting teeth's buccal bone plate and buccal root resorption.

3.4 Stress Distribution

On visual observation of Hartono *et al.* (2018) study, the color map of maxillary expansion simulation on miniscrews in Mini-Screw Expander (MSE) group displayed a stress concentration localized at the anterior miniscrews. MaxPS (highest tension) distribution showed left anterior miniscrews as the area that received the highest tension, while MinPS (highest compression) distribution showed right anterior miniscrews as the area that received highest compression. Lee *et al.* (2014) analyzed stress distribution and displacement of both maxilla and teeth according to different designs of RME using mini-screws on a 3D skull model. Type 1 showed that stress was concentrated around the micro-implants and the mid-palatal suture with a maximum value of 0.362 GPa. No stresses were observed around the roots. Weaker stresses were distributed through the lingual alveolar bone of the first premolar in cross section. On the other hand, type 2 demonstrated low stresses distributed evenly around the mini-screws. The cross-sectional view of the first premolar area showed the least amount of stress around the roots. Stresses concentrated in the mid-palatal suture were less than those in type 1 with a maximum value of 0.046 GPa. Type 3 had a large amount of

stresses located in the mid-palatal suture and around micro-implants and roots of the anchor teeth. Maximum stress concentration (0.368 GPa) was shown around the roots of the first premolar in the cross section. Also, in type 4, high stresses were concentrated around the anchor teeth with a maximum value of 0.016 GPa and smaller amounts on the palatal slope. The cross-sectional view showed concentrations of stresses around the roots and alveolar bone. However, weak stresses were located in the mid-palatal suture.

New appliances, such as the MARPE have been tested in orthodontic patients with the intent to avoid the unwanted side effects of traditional RPE. While the MARPE has shown evidence of clinical success, most are limited in the precise evaluation of the biomechanical effect of orthopedic forces, and it is difficult to suggest exactly what is physiologically occurring. Recent studies (Lee *et al.*, 2009; Gautam *et al.*, 2007; Jafari *et al.*, 2003) have demonstrated that Finite Element Method (FEM) is a viable method to study stress, strain, and force distributions when evaluating orthodontic problems, specifically transverse deficiencies. In a non-invasive way, FEM makes it possible to compare the effects of conventional hyrax and MARPE expansion forces on the craniofacial complex. (MacGinnis *et al.*, 2014).

IV. CONCLUSION

Despite the action of MARPE on the correction of transverse maxillary deficiency and the stability of this result, it is still early to state that it is a method that excludes dental effects. Studies have been promising in this regard, however, further research with a priori sample size, a well-designed randomized trials and meta – analysis data on the effects caused, standardization in the measurement of these and long-term assessments is necessary.

In addition, most articles have allowed to conclude that there is a strong recommendation of the MARPE method for non-growing patients and, researches using mini implants and skeletal anchorage have been shown to be effective and satisfactory, demonstrating the advance that Orthodontics has been suffering, where there is a high concern about treating the problem by reducing side effects and maximizing the effect of treatment.

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