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Factors to evaluate in CBCT images for maxillary disjunction using MARPE method – narrative review

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ABSTRACT

The disjunction of the maxilla in order to correct the atresia of the maxillary dental arch consists of opening the intermaxillary suture and consequent transverse increase of the skeletal base. This study aimed to evaluate, through a narrative review, the factors to be considered in the Cone-beam Computed Tomography (CBCT) for "Micro implant Assisted Rapid Maxillary Expansion" (MARPE) disjunction in the palatal suture. In order to identify relevant studies, a search was performed in the database Medical Literature Analysis and Retrieval System Online (MedLine) using 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 research results allowed us to conclude that CBCT images are very important to evaluate the parameters to be applied in the treatment using MARPE method.

Keywords: "Orthodontic Anchorage"; "Maxillary Expansion"; "CBCT"; "3D".

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, os fatores a serem considerados na "Cone-beam Computed Tomography" (CBCT) realizada antes da disjunção, através do método "Microimplant Assisted Rapid Maxillary Expansion" (MARPE) na sutura palatina. Foi realizada uma pesquisa na base de dados "Medical Literature Analisys and RetrievalSystem Online" (MedLine) através do motor de busca PubMed, de artigos publicadosentre os anos de 2010 a 2021. A seleção dos estudos respeitou os critérios de inclusãoe exclusão pré-definidos. Após a avaliação dos artigos selecionados, o resultado da pesquisa permitiu concluir que as imagens, de feixe cónico da tomografia computadorizada, são muito importantes na avaliaçãodos parâmetros aplicados no tratamento com MARPE.

Palavras-chave: "Ancoragem Ortodôntica"; "Expansão Maxilar"; "CBCT"; "3D".

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SUMMARY

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LIST OF ABBREVIATIONS AND ACRONYMS

ANSYS - Analysis System

BBME - Bone-Borne Maxillary Expander

CBCT - Cone-beam Computed Tomography

CT - Computed Tomography

DICOM - Digital Image and Communication in Medicine

FEM - Finite Element Method Analysis

MARPE - Mini-screw Assisted Rapid Palatal Expansion

MEDLINE - Medical Literature Analysis and Retrieval System Online

MSE - Mini-Screw Expansion

MPS - Mid Palatal Suture

RME - Rapid Maxillary Expansion

RPE - Rapid Palatal Expansion

SARPE - Surgically Assisted Rapid Palatal Expansion

TBME - Tooth-Borne Maxillary Expander

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 analysed 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. 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 induce 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*., 2013).

Regarding periodontics as 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 RME. 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).

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

Recently, Angelieri *et al.* (2013) have proposed methods to stage skeletal maturation of the mid-palatal suture, since it is believed that the degree of the skeletal or dentoalveolar effect of the maxillary expansion procedure, may be correlated to the maturation of the mid palatal suture and rigid interdigitations (progressive calcification), making it more resistant to split as age progresses.

The great advantage of CBCT compared to bidimensional dental radiographs is the absence of superimposition of anatomical structures. Besides the visualization of multiplanar sections in axial, coronal and sagittal planes, the images provide accuracy of approximately 0.2 mm, which is adequate for clinical applicable measurements (Nojima *et al.*,2018).

Orthopantomography or occlusal radiograph are adequate for assessing the opening of the mid palatal suture. However tooth movement, anatomical markings, bone anatomy and pathology are barely identifiable on these conventional two-dimensional radiographs. CBCT allows better imaging at low radiation dosages and presents a clear view of bony structures, tooth position, and type of palatal suture fusion with minimal image distortion (Bud *et al*., 2021).

The digital measurement tools, provided in software for digital image and communicationin medicine (DICOM), allow measurement of any distance, area or volume in acquired images. These characteristics are important to evaluate the bone thickness at areas

adjacent to the mid palatal suture, where miniscrews are inserted according to the planning for MARPE (Nojima *et al.*, 2018).

The aim of the present narrative review is to evaluate and analyse the factors to be considered in CBCT images for maxillary disjunctions using MARPE method, that can help professionals to start treatment using this method. Furthermore, palatal expansion is one of the most common problems faced by orthodontists and it is very important to correlate findings that could be helpful in daily routine.

1. Materials and Methods

The keywords were chosen and a computerized search was conducted on the search engine PubMed, selecting articles published from 2010 to 2021. The inclusion criteria were select articles which included measurements and evaluations with CBCT data and MARPE disjunction method in patients of any age or sex. The eligibility of potential studies was determined by reading the title and abstracts of each article identified.

As a result of the bibliographic search, 34 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 craniofacial malformations or syndromes and previous history of trauma or surgery in the study area.

A total of 8 articles, published between 2010 and 2021 met the inclusion criteria and were selected for analysis and data extraction.

II. DEVELOPMENT

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 RME (MacGinnis *et al*., 2014).

RME 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). It 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).

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, 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. 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 (Angelieri *et al*., 2013). This method might provide reliable parameters for the protocol for selection of miniscrew length in MARPE.

2. Mini-screw Assisted Palatal Expansion – MARPE

The use of miniscrews in palatal area was firstly introduced, because palatal is covered with keratinized gingiva and give good flexibility. The 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 RME (Haas-type and Hyrax-type) alone gave smaller effects at the skeletal level and Lagravere *et al.* (2005) referred that the effects of RME with bone anchorage produced less dental tipping than rapid maxillary expander alone. Those studies (Weissheimer *et al*., 2011; Lagravere *et al*., 2005) reported that MARPE were effective in preventing the negative side effects that were commonly seen with RME 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.

Bone anchored expander were reported to transmit a direct expansion force to the palatal bone, which contribute to a more skeletal opening of the suture, instead of bending the maxillary alveolar bone, as the force vector located near the bone (Hartono *et al.,* 2018). The fixation of miniscrews must be bicortical, including the cortical of the palate and nasal fossa, this being essential to overcome the resistance of the maxillary bone separation (Nojima*et al*., 2018).

The MARPE technique proposed by Lee *et al.* (2010) comprises the insertion of four miniscrews adjacent to the mid palatal 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, respectively, from 3.77 to 3.88mm and from 2.33 to 2.44 mm (Marchezan *et al*., 2012). Similarly, the soft tissues present variation in thickness of 2.6 to 2.8mm and 1.75 to 1.82 mm, respectively, at the regions mesial and distal to the expanding screw. This variability in bone and soft tissue thickness, associated with the height of the fixation ring of the expander miniscrew and its distance in relation to the soft tissue, contribute to the appropriate selection of the miniscrew length.

From a clinical perspective, placement of the miniscrew should be as close to the centre of resistance, to effect a more translatory movement of the maxillary halves. It is believed that, with a more rigid expansion appliance, the centre of rotation will move superior and posteriorly (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 centre of the maxilla through the miniscrews, a force system is promoted that favours a homogeneous and parallel opening of the suture (Lee *et al*., 2014; MacGinnis *et al*., 2014).

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

3. Factors to be considered using CBCT images

Identify cortical bone thickness at the site of miniscrew placement is a factor to consider for achieving their primary stability and to choose the appropriate miniscrew length avoiding perforations in the nasal cavity floor. Also the knowledge of soft tissue thickness helps in determining the overall implant length and implant collar height (Marchezan *et al*., 2012).

Clinical examination, panoramic and cephalometric radiographs have limitations when assessing the amount of bone tissue in the palate. Recent studies (Marchezan *et al*., 2012) have shown that computed tomography (CT) is a good method to evaluate the bone site most suitable for miniscrew placement since there is no distortion and superimposition of images. CBCT is alsoa good tool to evaluate soft tissue thickness. A study proposed by Marchezan *et al.* (2012) aimed to evaluate the thickness of cortical bone, total bone, and mucosa in the palatine suture and paramedian areas using CBCT to verify the most suitable areas for miniscrew placement. Patients of both genders who had tomography performed as part of their orthodontic exams were included. Their age range was 12 to 52 years old, so the sample comprised growing patients and adults, in order to evaluate the influence of age on palatal tissues. Their results concluded that the most suitable areas for receiving miniscrews are located along the suture, and in the paramedian region, 3 mm lateral to the suture. When evaluating mucosa measurements the values decreased from the lateral to median sites and were smaller at the suture.

Oliveira *et al*. (2021) conducted a study that aimed to evaluate whether MARPE success in mature patients was related to factors such as mid palatal suture (MPS) maturation, age, sex, and bicortical miniscrew anchorage. CBCT scans were taken, and the data were exported in the DICOM format and analyzed using NemoStudio software. T0 images were used to determine MPS maturational stages of the patients, according to Angelieri *et al*. T1 images were oriented to perform the skeletal transverse measurements in both anterior and posterior regionsof the palate, to quantify palatal expansion. In the axial cross-section passing through the infraorbital foramens, a measurement was made to quantify expansion on the midface. Maxillary changes were obtained by calculating the difference between the linear measurements (T1- T0). To assess bicortical miniscrew anchorage in the palate and the nasal cavity floor, the sagittal and coronal cross-sections at T1 were adjusted to pass through the long axis of each miniscrew. The results showed that the success rate decreased as MPS maturation increased. Bicortical miniscrew anchorage had no correlation with MARPE success or any of the skeletal measures. The highest success rate for suture opening was in cases without bicortical anchorage of the four miniscrews (80%). The cases with four and two miniscrews with bicortical anchorage had success rates of 70.5% and 66.6%, respectively. Regarding MPS maturation, Angelieri *et al.* (2013) performed a research aiming to present a novel classification method for the individual assessment of mid palatal suture morphology, using CBCT images, because RME is an unpredictable treatment for late adolescent and young adult patients. According to this study, the following descriptive stages of midpalatal suture maturation were proposed (Figure 1):

1. Stage A – Mid palatal suture is almost a straight high-density sutural line withno or little interdigitation;
2. Stage B – Mid palatal suture assumes an irregular shape and appears as a scalloped high-density line;
3. Stage C – Mid palatal suture appears as two parallel, scalloped, high-density lines thatare close to each other, separated by small low-density spaces in the maxillary andpalatine bones. The suture can be arranged in either a straight or an irregular pattern;

4. Stage D - Fusion of the mid palatal suture has occurred in the palatine bone, with maturation progressing from posterior to anterior. In the palatine bone, the mid palatal suture cannot be visualized at this stage. In the maxillary portion of the suture, fusion has not yet occurred, and the suture still can be seen as two high-density lines separated by small low-density spaces;
5. Stage E – Fusion of the mid palatal suture has occurred in the maxilla. The actual suture is not visible in, at least, a portion of the maxilla. The bone density is the same as in other regions of the palate.

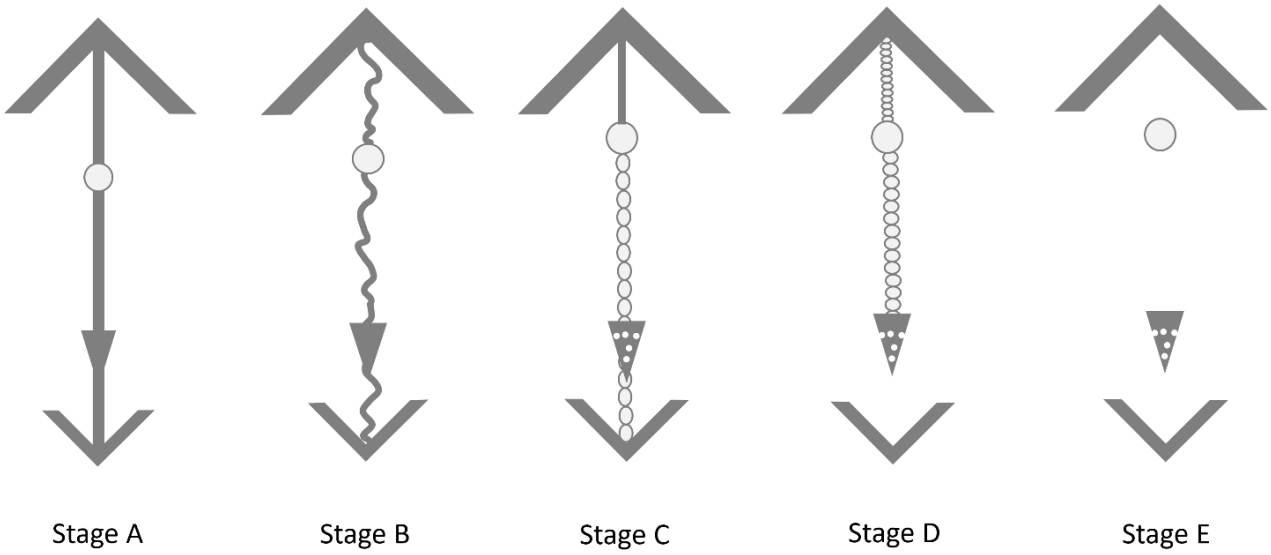

Figure 1 - Stages of maturation in the mid palatal suture.

The classification of mid palatal sutural fusion using CBCT allows the diagnosis of the overall anteroposterior characteristics of the mid palatal suture, without overlapping of other anatomic structures. This method might provide reliable parameters for the clinical decision and protocol using MARPE (Figure 2).

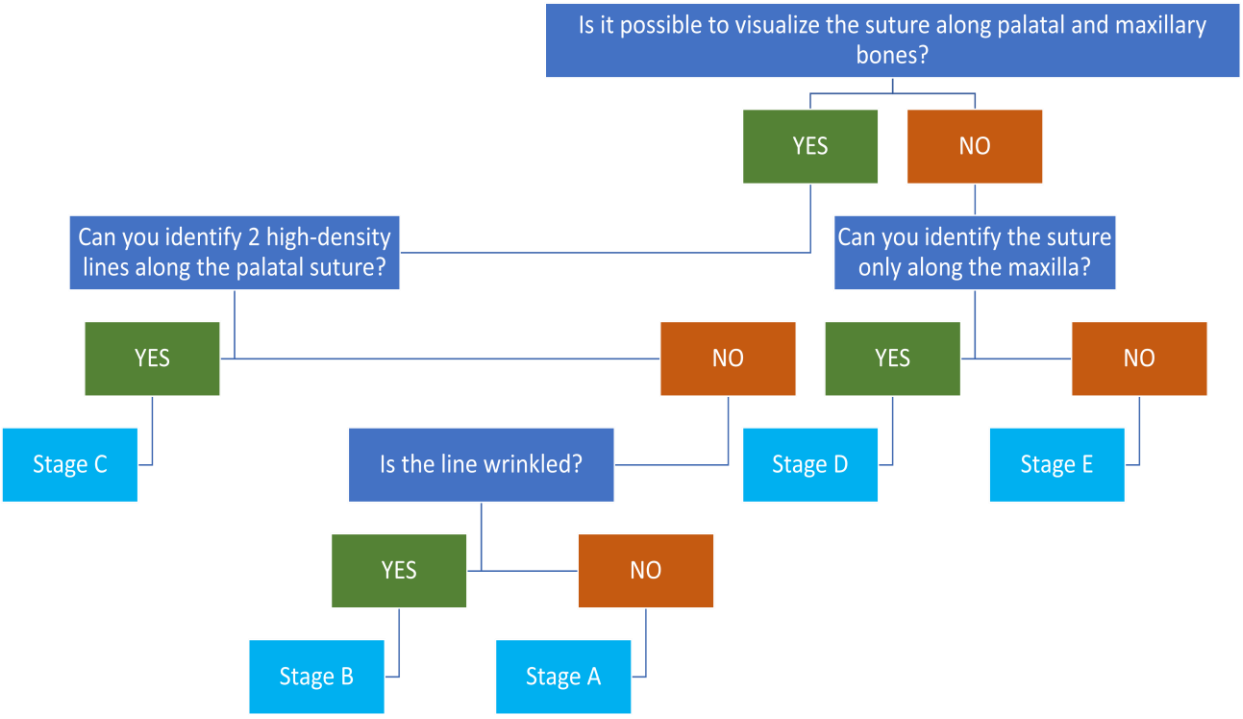

Figure 2 - Maturation stages of the midpalatal suture.

4. Palatine Suture

Due to the higher interdigitation of the midpalatal suture after puberty, McNamara and Brudon (1993) affirmed that expansion of the maxilla in post-pubertal patients is not feasible, andsurgically assisted rapid palatal expansion (SARPE) is needed. However, recent evidence has suggested that a successful expansion of the midpalatal suture in late adolescents can be possible with bone-borne and tooth-borne palatal expanders (MacGinnis *et al*., 2014; Carlson *et al*., 2016). Although MARPE appliances have been developed with the aim of enhancing the orthopedic effect of maxillary expansion, comparisons between tooth-borne and bone-borne expanders led to different results. In fact, Lin *et al.* (2015) found greater skeletal expansion with a bone-borne appliance, while Lagravère *et al.* (2013) reported that the two types of expanders generate similar skeletal effects.

Traditionally, analysis of the midpalatal suture during rapid palatal expansion (RPE) was conducted using study models (Gurel *et al*., 2010), two-dimensional imaging (Wertz and

Dreskin, 1977), and, more recently, 3-dimensional (3D) imaging based on CT data (Leonardi *et al*., 2011). The introduction of CBCT in the orthodontic field and the development of new computer software allows for multiplanar, 3D reconstructions, and, thus, more possibilities in diagnosis of the craniofacial complex in livingsubjects (Cevidanes *et al*., 2005).

III. DISCUSSION

1. Palatine Suture

Krusi *et al*. (2019) findings shows that several skeletal maxillary relevant differences were identified. Their study, which was 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. One trial indicated that bone-borne RME was associatedwith 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 3D mesh model ofthe cranium with associated maxillary sutures was developed using CT images and mimics modelling software, refers that by placing expansion forces closer to the maxilla's centre of resistance, less tipping occurs with a more lateral translation of the complex. Additionally, this study compared transverse expansion stresses in 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 inpatients with sutures that are fused. 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: the benefits of MARPE in sutures that are already fused, and the great advantage of having CBCT images to evaluate those parameters, allowing to succeed in orthopedic and orthodontic treatment.

Mosleh *et al*. (2015) evaluated and compared the transverse dentoskeletal changes concurrent with 4-point bone-borne maxillary expander (BBME) and tooth-borne maxillary expander (TBME) in growing female patients with 12 years old. A superimposition from before and after 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 or miniscrew-supported 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. 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. Furthermore, it is of great value having CBCT images to rely on and help dentists to determine the amount of suture fusion and also the real quantity of opening.

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 andleft 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 interfere our reliability in drawing clinical recommendations (Krusi *et al*., 2019).

2. The use of CBCT Images

CBCT scanners render high-resolution images with lower doses of radiation compared with spiral CT. For these reasons, 3D CBCTs are the method of choice in evaluating the complex dentofacial structures. Cross-sectional cuts in axial, coronal and sagittal planes permit access to the internal morphology of soft tissues and skeletal structures. The challenges in utilizing the 3D CBCT images include compilation of software for construction of the 3D models and the assessment of changes after the treatment. Various techniques for the reconstruction of 3D CT images have been used in diagnosis, treatment planning and simulation.

Cevidanes *et al*. (2005) concluded that the visualization of 3D model superimposition and the surface distance calculations can help orthodontists, surgeons and other healthcare providers to a better treatment plan.

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, a well-designed randomized trial, a meta–analysis data on the caused effects, a standardization in the measurement and a long-term assessment is necessary.

In addition, most articles have allowed to conclude that there is a strong recommendation of the MARPE method for non-growing patients. Research using miniscrews and skeletal anchorage have been effective and satisfactory, demonstrating the advance in orthodontics treatment, reducing side effects and maximizing the effect of treatment.

With this propose CBCT images are very important to evaluate the parameters to be applied in the treatment using MARPE.

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